



Review Article

Beneficial ingredients in black coffee and their health benefits in today's lifestyle — A review

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Abstract

Black coffee is a widely distributed drink whose demand has increased with urban lifestyles. In addition to caffeine, coffee has a complex combination of bioactive molecules—chlorogenic acids, trigonelline, diterpenes (cafestol, kahweol), melanoidins, and other polyphenols—which exert antioxidant, anti-inflammatory, metabolic, neuroprotective, hepatoprotective, and microbiome-modulating effects. This review distills the chemical composition of black coffee, their postulated mode of action, and clinical and epidemiological data for health outcomes (mortality, cardiometabolic disease, liver disease, neurodegeneration, cancer, and gut health). It highlights practical issues (method of brewing, addition of other substances, timing) of interest in contemporary lifestyle and delineates safety precautions.

Keywords: Black coffee, Bioactive compounds, Chlorogenic acids, Caffeine, Trigonelline, Diterpenes

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1. Introduction

Coffee is one of the world's best-selling drinks, only rivalled by water in most nations, and its consumption has kept increasing in today's societies. Over two billion cups of coffee are estimated to be drunk every day around the world, rendering it not only a cultural icon but also a major source of dietary exposure to bioactive compounds.¹ Black coffee has long been valued for its energizing qualities, which are largely due to caffeine, but new research highlights that it is much more than just a beverage to enhance energy levels. It is a polyphenol-alkaloid-diterpene-melanoidin-micronutrient mixture, whose many of its components have biologically significant actions on human physiology.^{2,3} Lifestyle modifications in recent times, with urbanization, physically inactive work, non-time structured eating, disturbance of sleep, and high rates of metabolic and neurodegenerative diseases, have also heightened scientific interest in coffee's implications for health. In contrast to highly sweetened or calorie-fortified coffee drinks that are now pervasive in café culture, black coffee has essentially zero calories yet delivers high levels of health-promoting compounds.⁴ A key difference is notable because black coffee may offer

protection against the same conditions as sugar- and fat-coated coffee drinks, which can increase the risk of obesity, insulin resistance, and cardiovascular disease.⁵ Over the past two decades, large-scale epidemiological studies and meta-analyses have consistently reported associations between moderate coffee consumption and reduced risk of several chronic diseases, including type 2 diabetes, cardiovascular disease, liver disease, and neurodegenerative conditions such as Parkinson's disease.^{3,6,7}

Additionally, coffee has been linked to lower all-cause mortality in multiple population cohorts.⁸ These connections persist in both caffeinated and decaffeinated coffee, showing that non-caffeine components—like chlorogenic acids and melanoidins—are crucial in mediating health effects.^{2,6} Mechanistic studies also confirm these findings. Coffee's bioactive components act on critical physiological pathways, including glucose and lipid metabolism, oxidative stress, inflammation, neuronal signalling, and gut microbiota structure.^{6,9,10} For example, chlorogenic acids have been found to enhance insulin sensitivity and lower oxidative damage, while adenosine receptor antagonism by caffeine accounts for both its neuroactive effects and its link with

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diminished Parkinson's risk.^{7,10} Even though these are encouraging results, subtleties exist. The health consequences of coffee depend on dose, preparation method, and personal factors like genetic makeup, age, and comorbidities. Unfiltered brewing techniques (e.g., boiled coffee or French press coffee) preserve lipid-elevating diterpenes such as cafestol and kahweol, which can raise serum cholesterol, but filtered coffee eliminates these substances.⁷ Similarly, chronic overconsumption of caffeine can interfere with sleep, worsen anxiety, and be dangerous during pregnancy, so moderation is essential.⁴

2. Principal Bioactive Molecules in Black Coffee

Black coffee contains several bioactive compounds. Table 1 sums up major bioactive compounds in black coffee and their primary health effects.

- 1. *Caffeine*: A methylxanthine adenosine-receptor antagonist with widely researched central nervous system stimulatory effects; also linked to neuroprotection, energy expenditure modulation, and certain cardiometabolic pathways.^{4,5}
- 2. *Chlorogenic acids (CGAs) and phenolic relatives*: CGAs (caffeic and quinic acid esters) are common

- polyphenols in coffee. They have antioxidant, anti-inflammatory, and glucose-modulating activities in preclinical and clinical research. CGAs are proposed mediators of coffee's relationship with reduced type 2 diabetes risk.^{3,6}
- 3. *Trigonelline*: A niacin pathway-derived alkaloid; demonstrates neuroprotection and putative antidiabetic activity in preclinical models and imparts flavour (aroma) when subject to heat.¹
- 4. *Diterpenes*: Cafestol and Kahweol: These diterpenes, which are soluble in oil, are anti-inflammatory and anticarcinogenic in model systems but increase serum LDL and total cholesterol when ingested in unfiltered brews (e.g., boiled, French press, certain espressos)—a significant real-world trade-off dictated largely by brewing method.^{7,8}
- 5. *Melanoidins (Maillard reaction polymers)*: Developed in roasting, melanoidins are responsible for coffee's antioxidant activity and possibly function as dietary fiber-like substances which modulate gut microbiota and possess antioxidant/chelation activity.^{9,6}
- 6. *Minor compounds and minerals*: trace levels of vitamins, minerals, and other phenolics (e.g., caffeic acid) also contribute to coffee's biological profile.¹

Table 1: Major bioactive compounds in black coffee and their primary health effects

Bioactive Compound	Chemical Class	Key Biological Activities	Health Effects (Evidence Level)	Representative References
Caffeine	Methylxanthine alkaloid	Adenosine receptor antagonist; CNS stimulant; increases energy expenditure; modulates dopaminergic pathways	Improved alertness, neuroprotection (Parkinson's), potential CVD safety at moderate intake	4,5,10
Chlorogenic acids (CGAs)	Polyphenols (caffeoylquinic esters)	Antioxidant, anti-inflammatory, modulate glucose absorption, improve insulin sensitivity	Lower type 2 diabetes risk; possible CVD & cancer protective effects	3,6,11
Trigonelline	Alkaloid (niacin-related)	Neuroprotective, hypoglycemic effects in models; flavor precursor	May support cognitive health, potential anti-diabetic action	1,10
Cafestol & Kahweol	Diterpenes (lipid-soluble)	Anti-inflammatory, anticarcinogenic; raise serum LDL when unfiltered	Potential anti-cancer effects; adverse lipid profile if unfiltered	7,8,22
Melanoidins	Maillard reaction polymers	Antioxidant, metal-chelation, dietary fiber-like activity; microbiome modulation	Improved gut health; antioxidant capacity	9,13
Minor polyphenols (e.g., caffeic acid)	Phenolic acids	Antioxidant, anti-inflammatory	Contribute to reduced oxidative stress	1,6

Table 2: Brewing methods and relative diterpene (cafestol/kahweol) exposure

Brewing Method	Filtration	Relative Diterpene Content	Impact on Serum Lipids	Health Implication	References
Filtered drip coffee (paper filter)	Paper filtration	Very low (most cafestol/kahweol removed)	Neutral	Safe for individuals with hypercholesterolemia	7,8
Espresso	Metal filter (short contact time)	Moderate (less than boiled but higher than paper filter)	Mild LDL increase possible with high intake	Acceptable in moderation	7,22
French press / plunger	Metal mesh filter	High	Significant LDL increase with frequent intake	Limit in those with dyslipidaemia	8,22
Boiled coffee (e.g., Scandinavian, Turkish)	No filtration	Very high	Marked LDL increase	Discouraged in hypercholesterolemic patients	7,8
Instant coffee	Industrially processed	Low (diterpenes largely removed)	Neutral	Safe option	7

3. Mechanisms of Action: How Coffee Bioactives Might Influence Health

1. *Antioxidant & anti-inflammatory actions:* CGAs, melanoidins, and other polyphenols neutralize free radicals and regulate inflammatory pathways, lowering oxidative stress burden.^{6,9}
2. *Metabolic modulation:* CGAs and other phenolics enhance glucose tolerance, insulin sensitivity, and adipokine profiles in observational and some mechanistic studies—potential mediators of decreased diabetes risk.³
3. *Neuroprotection:* Caffeine inhibits adenosine receptors and alters microglial activation, whereas CGAs and trigonelline exhibit antioxidant/neuroprotective action in preclinical models—mechanisms evoked for reduced Parkinson's and potentially Alzheimer's risk.^{5,10}
4. *Hepatoprotective mechanisms:* Several coffee constituents (caffeine and polyphenols) have been found to dampen inflammation, fibrosis, and carcinogenesis in liver disease models and epidemiological research.^{11,12}
5. *Gut microbiota and motility:* Melanoidins and coffee polyphenols regulate the composition of gut microbiota and can favor beneficial bacteria and bowel function.¹³

4. Health Consequences and the Evidence

1. *All-cause and cause-specific mortality:* There is a consistent demonstration across large prospective studies and meta-analyses of association between moderate coffee consumption (usually 2–4 cups/day) and reduced all-cause and cause-specific mortality (cardiovascular disease and certain cancers) with a U-shaped or plateau at higher consumption in most cohorts. The associations are present for caffeinated and decaffeinated coffee, indicating non-caffeine content contributes.^{2,14}
2. *Type 2 diabetes (T2D):* Meta-analyses and prospective cohort studies in pools show a reverse association: per

additional cup/day is linked to about a 7–9% decreased relative risk of T2D development (strong epidemiologic evidence). CGAs, magnesium, and other coffee components are likely mediators.^{3,15}

3. *Cardiovascular disease (CVD):* Current overviews indicate moderate coffee drinking is neutral or modestly protective for cardiovascular disease outcomes (coronary heart disease, stroke) in most populations, particularly if drunk black or with low-calorie modifications. Nevertheless, unfiltered high-cafestol intake may elevate LDL cholesterol and thus enhance CVD risk in susceptible subjects—demonstrating the contribution of brewing method. Mendelian randomization analyses yield inconclusive evidence regarding causality; the net balance of observational evidence points to moderate consumption as safe or healthy for many individuals.^{4,8,16}
4. *Liver disease and hepatocellular carcinoma (HCC):* Several systematic reviews and dose-response meta-analyses report strong inverse associations between coffee drinking and chronic liver disease, cirrhosis, and HCC. Estimates are varied, but some meta-analyses report large risk reductions (e.g., ~30–40% reduced HCC risk with greater coffee consumption). Caffeine and CGAs are putative protective agents.^{12,17}
5. *Neurodegenerative disorders (Parkinson's and Alzheimer's):* Epidemiological data demonstrate a consistent reverse correlation of coffee consumption (especially caffeinated) with incidence of Parkinson's disease; evidence for Alzheimer's disease is less robust but suggestive of cognitive advantage and reduced risk of dementia in certain cohorts. Mechanisms are adenosine receptor blocking (caffeine), antioxidant properties, and neuroinflammatory modulation.^{5,10,18}
6. *Cancer (except HCC):* The evidence for coffee and cancers is heterogeneous. For certain cancers (e.g., endometrial, liver), reduced risk relates to coffee consumption; for others, findings are null or mixed. Meta-analyses provide protective hints for some malignancies but highlight heterogeneity and residual confounding.^{11,12}

7. *Gut microbiota, microbiome, and bowel health:* Recent human and animal research reveals that coffee and its melanoidins/polyphenols influence the composition of gut microbiota, can enhance beneficial bacterial populations, and can positively affect bowel motility and products of fermentation. The mechanisms are an active area of investigation with possible relevance to metabolic and neuroimmune routes.^{9,13}
8. *Antioxidant and inflammation markers (short-term/intervention data):* In vitro and simulated digestion studies, together with small human feeding trials, indicate that drinking coffee raises plasma antioxidant activity and lowers certain inflammatory markers, though clinical relevance and longevity of these changes need larger long-term RCTs.⁶

4.1. Safety, caveats, and special populations

1. *Pregnancy:* Excessive caffeine consumption is avoided during pregnancy due to miscarriage and foetal growth restriction associations; most guidelines advise restraint from caffeine (e.g., <200 mg/day), so black coffee consumption must be restrained. (Note: for pregnancy-specific recommendations, refer to obstetrics recommendations.).⁴
2. *Hypercholesterolemia / CVD risk:* High LDL cholesterol individuals should not consume regular unfiltered coffee (diterpenes present) and choose paper-filtered coffee.^{7,22}
3. *Sleep & anxiety:* Excessive caffeine can exacerbate sleep, anxiety, and arrhythmias in susceptible individuals. Moderation in dosage is the answer.⁴

5. Brewing Method, Preparation, and Contemporary Lifestyle Significance

The health impact of black coffee is closely tied to its brewing method and preparation. Paper-filtered coffee (e.g., drip, pour-over) effectively removes lipid-raising diterpenes, making it the preferred option for cardiovascular protection, whereas unfiltered methods such as French press or boiled coffee retain higher diterpene levels and may increase cholesterol.^{1,2} Espresso, increasingly popular in urban settings, provides concentrated caffeine with moderate diterpene exposure. From a lifestyle perspective, the choice of preparation reflects not only cultural trends but also health consciousness: individuals opting for black, unsweetened, filtered coffee align their beverage habits with preventive health strategies, avoiding the excess calories and sugars prevalent in commercial coffee drinks. Thus, black coffee offers convenience, affordability, and health benefits backed by science, making it a functional beverage and a lifestyle marker in today's fast-paced world. The Table 2 summarises brewing methods and relative diterpene (cafestol/kahweol) exposure

1. *Filtered vs. unfiltered coffee:* Paper filtration eliminates virtually all diterpenes (cafestol/kahweol) and therefore all but eliminates the cholesterol-raising

effect of boiled, French press-type unfiltered brews—a practical solution for individuals worried about LDL cholesterol.^{8,7}

2. *Black coffee versus additives:* Most contemporary coffee customs (sugary lattes, flavored syrups, whipped cream) add calories, saturated fat, and sugars that counteract or reverse coffee's metabolic advantage. Evidence indicates black coffee is the most consistent with beneficial outcomes; adding large quantities of sugar or cream diminishes those advantages.^{19,20}
3. *Timing:* Current evidence indicates timing of eating (e.g., morning) could be important for circadian entrainment and certain mortality/CVD relations, but findings are novel and emerging. Late-evening eating remains to be avoided due to nighttime disturbance.^{21,20}

6. Discussion

The contemporary lifestyle is dominated by accelerated urbanization, heightened sedentary behaviour, abnormal eating habits, protracted psychological stress, and prevalent circadian disturbance owing to shift work and nocturnal exposure to screens. These modifications have added to the growing worldwide burden of metabolic syndrome, type 2 diabetes mellitus, cardiovascular disease, neurodegeneration, and some cancers.^{1,2} Here, the contribution of diet — especially the consumption of low-calorie, functional drinks — has increasingly played a critical role in preventive health approaches. Black coffee's high concentration of bioactive compounds, low calorie content, and widespread cultural acceptance make it a potentially protective beverage when consumed without sugar or cream.^{3,4}

1. *Black coffee as a counterbalance to sedentary habits and poor diets:* Sedentary habits in conjunction with diets high in refined carbs and unwanted fats have driven the obesity and insulin resistance epidemic. Evidence indicates that chlorogenic acids and other polyphenols in black coffee enhance insulin sensitivity, regulate glucose metabolism, and lower oxidative stress, hence the risk of type 2 diabetes.^{5,6} In contrast to sugar-containing specialty coffee drinks, which increase metabolic risk, black coffee is metabolically protective without contributing extra calories and, therefore, is well-suited to current populations seeking less energy-dense options for beverages.^{4,7}
2. *Neurocognitive protection in a stressed, sleep-deprived world:* Chronic stress, sleep disruption, and cognitive overload are prevalent features of modern society. Caffeine, the best-researched substance in coffee, not only increases alertness and psychomotor function but also shows long-term neuroprotective benefits, most importantly in neuroprotection against Parkinson's disease.^{8,9} Furthermore, trigonelline and chlorogenic acids show antioxidant and anti-inflammatory actions on neuronal cells, indicating a synergistic neuroprotective pattern.¹⁰ Although

excessive caffeine consumption can exacerbate sleep disturbances, appropriate and moderate use can enhance cognitive function and resistance to mental fatigue in contemporary work settings.⁹

3. *Cardiometabolic health in the chronic disease era:* Cardiovascular disease is still the most prevalent cause of death worldwide. Global patterns of diet, along with increasing obesity and diabetes, have amplified cardiovascular risk. Moderate black coffee intake has been uniformly linked with either neutral or weakly protective cardiovascular effects, especially if consumed via filtered brews that avoid diterpene-induced lipid increases.^{11,12} Unfiltered coffee (French press, boiled) will aggravate cholesterol profiles and needs moderation, particularly in patients with dyslipidaemia.¹² Thus, preparation technique becomes a crucial factor in determining whether coffee consumption increases or decreases cardiovascular stress.
4. *Liver protection in the setting of lifestyle-related liver diseases:* The increasing prevalence of non-alcoholic fatty liver disease (NAFLD), fuelled by obesity, insulin resistance, and dietary overindulgence, underscores the necessity for affordable hepatoprotective therapies. Coffee drinking has been found to have strong inverse correlations with the progression of chronic liver disease, cirrhosis, and hepatocellular carcinoma.^{13,14} Caffeine and chlorogenic acids are responsible for these benefits through attenuation of hepatic inflammation and fibrosis. This evidence places black coffee as a low-cost, worldwide available nutritional factor with significant public health relevance to groups at risk of metabolic liver disease.
5. *The gut microbiome as an intermediary of contemporary health:* Increased awareness of the gut microbiota's influence on systemic health puts emphasis on nutrition factors that positively impact microbial composition. Melanoidins and polyphenols within black coffee are prebiotic-like substances that promote growth of beneficial bacteria and bowel regularity.¹⁵ As contemporary diets tend to be low in fiber and polyphenolic compounds from plants, black coffee could be used as an additive source of microbiota-modulating agents, which is in step with gut and metabolic health-promoting strategies.
6. *Equilibrium of advantage and disadvantage:* Although the balance of evidence favors health benefits of moderate intake of black coffee, one has to consider risks in context. Excessive intake of caffeine is likely to cause anxiety, disruption of sleep, arrhythmias, and pregnancy complications.^{4,9} Additionally, brewing technique and genetic variation within individuals in metabolizing caffeine affect outcomes, emphasizing personalization. The overarching message is that preparation method and moderation are important: 2–4 cups of filtered black coffee daily is uniformly linked to best results in most populations.^{8,11}
7. *Public health and contemporary dietary recommendations implications:* With its widespread

consumption, affordability, and cultural acceptance, black coffee is an underappreciated nutritional partner in the prevention of chronic disease. As public health initiatives promote reductions in sugar-sweetened drink consumption, marketing black coffee (and tea and water) as a healthy alternative option may fit with obesity, diabetes, and cardiovascular disease obviation efforts. Notably, the differentiation between black coffee and calorie-laden commercial coffee drinks should be highlighted in health education initiatives.

7. Limitations of the Evidence and Areas for Further Research

1. Most of the strong evidence is observational; residual confounding cannot be ruled out. Mendelian randomization and RCTs are increasing but are not conclusive for all outcomes.^{2,4}
2. Mechanistic heterogeneity: benefits are likely due to a combination of compounds (caffeine and non-caffeine bioactives) and lifestyle associations of coffee consumers; isolating the active components in humans is still difficult.^{1,10}
3. Dose, preparation, and population heterogeneity (caffeine metabolism genetics, comorbidities) require investigation.^{4,22}

8. Conclusion

Black coffee is not just a caffeinated drink; it is a multiplex source of bioactive compounds, such as caffeine, chlorogenic acids, trigonelline, diterpenes, and melanoidins, each with different health effects. Over the past two decades, robust epidemiological evidence, supported by mechanistic and interventional studies, has established moderate black coffee consumption as consistently associated with reduced risks of type 2 diabetes, chronic liver disease, hepatocellular carcinoma, and Parkinson's disease, alongside a modest reduction in all-cause and cardiovascular mortality.¹⁻⁴ In contrast to most contemporary high-sugar and high-fat drinks, black coffee offers these advantages without extra caloric cost, making it an increasingly appropriate option in current lifestyle, with obesity and metabolic disorder on the uprise.^{5,6} Notably, the health impacts of coffee are not consistent but depend on brewing, making method, preparation type, dose, and caffeine metabolism variability in individuals. Although paper-filtered black coffee is generally advantageous, unfiltered coffee increases serum cholesterol because of diterpenes, and too much caffeine can detrimentally impact sleep, anxiety, and pregnancy.⁷⁻⁹ These limitations highlight the maxim that moderation and brewing method count: maximum health benefit is reliably found at 2–4 cups daily of filtered black coffee in most groups.

Against the backdrop of lifestyle shifts in contemporary life—sedentary lifestyle, circadian disruption, excessive stress, and low quality of diet—black coffee has a special combination of protective benefits. Through enhanced glucose metabolism, increased neurocognitive resilience,

facilitation of liver function, and gut microbiome modulation, it has the potential to act as a preventive as well as adjunct diet against non-communicable disease burden.^{2,5,10} Its availability, accessibility, and worldwide cultural penetration further enhance its public health promise. Future studies need to elucidate causal mechanisms using randomized controlled trials, investigate dose–response relationships in diverse populations, and uncover genetic or metabolic subgroups that may be uniquely helped by or susceptible to coffee intake. In addition, public health communication needs to differentiate between black coffee and calorie-rich, commercially sweetened coffee drinks so that the possible benefits of coffee are not diluted by unhealthy ingredients.

In summary, moderate consumption of black coffee may be seen as more than just a daily habit; it can also be seen as a beverage that helps people fight against the health issues that come with living in the contemporary world. Black coffee can be accepted as a safe, enjoyable, and beneficial component of a healthy routine with careful consideration of preparation, moderation, and individualization.

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None.

10. Conflict of Interest

None.

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