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A review of the effectiveness of chlorogenic acid in green coffee for human health

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ABSTRACT

Chlorogenic acid (CGA) is a polyphenolic compound produced in certain plants, one of which is coffee. Green coffee has a higher CGA number than other types of coffee of the same weight. CGA is a compound that has been shown to be the main component of green coffee. The benefits of CGA as a healthy ingredient have been demonstrated in many studies. This review describes the effectiveness of green coffee CGA in reducing the number of illnesses that are dangerous to human health. In related literature, the effects of CGA have been reported in vitro, in vivo, and in clinical trials. CGA research in clinical trials is primarily focused on its antioxidant activity, human oxidative response, and the best results as an antioxidant. In this study, you will learn about the CGA stability and health tolerance of green coffee. We will also learn about the effectiveness of CGA for many aspects of its health effects by reviewing recent studies as our intent.

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1. INTRODUCTION

To date, the analysis and evaluation of bioactive compounds in coffee has been required. In fact, coffee roasting levels include dark, medium, and light. According to the test results, the third sample of roasted coffee showed the highest phenol content in the light and medium categories. Light roast coffee contained about 8.74 mg / g of polyphenols, and medium roast coffee contained about 7.95 mg/g of polyphenols (Król et al., 2020).

Unroasted coffee beans are popular because they are known as "mung beans" and contain a type of polyphenol called chlorogenic acid (CGA). CGA is known to have strong antioxidant activity (Roshan et al., 2018). In some countries, the content of green coffee is about 14% (dry matter). Arabica coffee contains 3.5 - 7.5% (w / w dry matter) CGA, and coffee canephora contains 7 - 14% (w/w dry matter) CGA. In fact, the CGA content of unroasted coffee is higher than that of roasted coffee (Pimpley et al., 2020).

Green coffee is commonly processed into a preparation known as Green Coffee Extract (GCE). Studies indicate that administration of higher doses of GCE, which is rich in chlorogenic acid (CGA), over extended periods may produce more favorable outcomes. Nevertheless, further investigations are required to establish its optimal efficacy and safe consumption levels for obesity management, particularly by examining variables such as dosage regimens and treatment duration.

Chlorogenic acid is an esterified phenolic compound formed from caffeic acid and (–)-quinic acid and serves as an important intermediate in the biosynthetic pathway of lignin. The designation "chlorogenic acid" encompasses a group of structurally related polyphenolic esters derived from the conjugation of quinic acid with various hydroxycinnamic acids, including caffeic, ferulic, and p-coumaric acids. According to the International Union of Pure and Applied Chemistry (IUPAC), chlorogenic acid is systematically named 1S,3R,4R,5R-3-{[(2E)-3-(3,4-dihydroxyphenyl)prop-2-enoyl]oxy}-4,5-trihydroxycyclohexanecarboxylic acid.

While CGA or chlorogenic acid uses "chloro" in its name, it does not have chlorine in the CGA chemical structure and is also not related to it. The name of CGA comes from the Greek, which means light green color. This is because CGA will shine and make this color during when oxidization process (Singh et al., 2020).

Chlorogenic acids can be categorized into three major groups, namely caffeoylquinic acids (CQAs), feruloylquinic acids (FQAs), and dicaffeoylquinic acids (diCQAs). Among these compounds, CQAs constitute the predominant fraction, accounting for approximately 91% of the total polyphenol content in green coffee and 73–85% in roasted coffee. The most abundant CQA isomer detected in green coffee is 5-O-CQA, followed by 4-O-CQA. During the roasting process, the degradation of CQA isomers has been reported to range from 20% to 54%, although losses generally remain below 24% when roasting is performed at 190°C. Feruloylquinic acids represent a smaller proportion of coffee polyphenols, contributing about 5% in green coffee and 7–12% in roasted coffee. Increased roasting air humidity has been associated with changes in FQA levels. The relative increase in FQAs observed after roasting may result from the extensive degradation of other polyphenolic constituents combined with the comparatively greater oxidative stability of ferulic acid. Structurally, FQAs belong to the monohydroxyphenol class and possess a second hydroxyl group that is acylated. Dicaffeoylquinic acids comprise approximately 3% of the polyphenolic compounds present in green coffee and about 2–4% in roasted coffee. The reduction in diCQA concentration during roasting, estimated at 17–53%, is comparable to that observed for monoester derivatives. Nevertheless, diesters are known to undergo substantial deacylation reactions, leading to the formation of corresponding monoesters or, in some cases, complete degradation of the original molecules (Pimpley et al., 2020).

In general, mono-caffeoylquinic acids (monoCQAs) exhibit greater stability than dicaffeoylquinic acids (diCQAs) when subjected to comparable environmental conditions. Differences in stability among diCQA isomers have also been reported. According to Xue et al. (2016), 4,5-diCQA demonstrates a higher degree of stability than both 3,4-diCQA and 3,5-diCQA. This variation is primarily associated with the position of the ester linkages on the quinic acid moiety. Ester bonds attached at equatorial positions tend to be more resistant to degradation than those located at axial positions. In the structures of 3,4-diCQA and 3,5-diCQA, only one ester group occupies an equatorial orientation, whereas both ester groups in 4,5-diCQA are situated in equatorial positions, contributing to its enhanced stability. Chlorogenic acid derivatives are highly sensitive to thermal treatment. Elevated temperatures accelerate a variety of chemical transformations, including intramolecular isomerization and transesterification reactions. In addition, increasing temperature promotes the breakdown of these compounds, leading to a reduction in their overall concentration and structural integrity (Xue et al., 2016).

CQAs are their substance precariousness and separation into different mixtures that address CGA parts. The warming of 5-CQA in water can cause it to isomerize and change to 4-CQA and 3-CQA. It can likewise go through different responses, for example, esterification, hydrolysis or expansion of water to double bonds. This can happen in any event, during its segregation from plant material, bringing about lower antioxidant activity of the phenolic compounds (Dawidowicz & Typek, 2017).

There are numerous analytical techniques to distinguish and evaluate chlorogenic acids in regular samples; however, there are no authoritative and universally accepted strategies for CQAs analysis. Consequently, numerous labs create and approve their own investigation strategies, even more of which rely upon the analytical procedure and various methodologies. It can be presumed

that liquid chromatography (LC) and capillary electrophoresis (CE) with various detection frameworks are the most commonly applied (Gil & Wianowska, 2017). The applicable written works express the impacts of CGAs in animal and human models, including clinical studies for cardiovascular, antioxidant activity, against cholesterol, against diabetes, against cancer-causing, anti-inflammatory, and particularly against weight impacts. Humans accept that drinking green coffee can diminish their body weight right away.

The main gap in scientific evidence regarding the effectiveness of chlorogenic acid (CGA) in humans, compared with in vitro (cell) and in vivo (animal) models, stems primarily from limited oral bioavailability, complex gut microbiota metabolism, and a lack of large-scale clinical validation. While laboratory and animal models provide highly controlled settings that show robust direct therapeutic activities, translating these results into human health benefits faces several distinct challenges, including: a) The bioavailability and concentration gap, b) Microbiota-dependent metabolism; c) Mechanistic explanations vs. broad clinical outcomes; d) Scale and mixed human trial results

While animal data overwhelmingly support the anti-obesity and antidiabetic properties of CGA, human trials are far more modest, often limited by short durations (typically 8 to 12 weeks) and small sample sizes. Additionally, human trials occasionally yield conflicting results—for example, some studies show significant improvements in insulin sensitivity, while others note no significant impact on gut-derived metabolic hormones (Gonthier et al., 2003; Nguyen et al., 2024; Zalewska et al., 2025).

In Indonesia, based on BPOM Regulation Number 24 of 2023, determining a safe dosage for ingredients such as CGA (Chlorogenic Acid, commonly found in green coffee extract) is crucial and must be strictly enforced before a product can be distributed.

The following are the fundamental regulatory reasons why this is a high priority for businesses: a) Absolute prerequisites for a distribution permit: meeting safety and quality requirements is a mandatory criterion for obtaining a distribution permit for health supplements in Indonesia. Without a clear determination of a safe dosage, a product will not be legally recognized by BPOM; b) Obligation to conduct technology and dosage studies for natural ingredients: that active ingredients from natural ingredients must be in the form of isolates, fractions, or extracts (CGA is generally applied in extract form); c) Strict contamination risk (caffeine sources only): If CGA is extracted from sources such as coffee (green coffee beans), this regulation pays special attention to the content of contaminants or accompanying active compounds. Based on Appendix I (Point 2), products containing coffee or other caffeinated herbs are strictly limited, with a maximum caffeine content of 50 mg/serving and not exceeding 150 mg/day. If coffee is used solely as a flavoring, the maximum content is 10 mg/serving. Therefore, the dosage of CGA extract must be calculated precisely to prevent the accompanying caffeine content from exceeding safe limits, which could pose a health risk.

4. Special assessment procedures (if not already regulated): If the safe dosage limit for a specific CGA is not stated in the Pharmacopoeia or the appendix to this regulation, Article 12 requires a formal assessment request to the Head of the Food and Drug Authority (BPOM) regarding the usual dosage and maximum limit, including toxicity data such as the Acceptable Daily Intake (ADI), No Observed Adverse Effect Level (NOAEL), and LD50 (Badan Pengawas Obat dan Makanan, 2023).

2. RESEARCH METHOD

This article is a review of several previously conducted studies. To systematically gather scientific evidence related to Chlorogenic Acid (CGA), researchers rely on highly structured literature search strategies. These methods ensure comprehensive data collection from primary medical, chemical, and pharmacological research databases. The primary article search strategies used to locate evidence on CGA include: targeted electronic database selection (PubMed, Scopus, Web of Science, Google Scholar, ScienceDirect, SpringerLink, Wiley Online Library, and Elsevier), comprehensive

keyword & boolean operators strategy, primary substance terms such as "chlorogenic acid" or "CGA" or "5-O-caffeoylquinic acid" or "green coffee bean extract", combining biological outcomes such as antioxidant, anti-inflammation, etc, study design and eligibility filtering such as clinical evidence and pre-clinical evidence (*in vitro*, *in vivo*, or animal models), and also manual reference snowballing (Lu et al., 2020; Nguyen et al., 2024). This article is a review of several previously conducted studies. This review article discusses the effectiveness of green coffee, including anti-inflammatory, anti-obesity, antioxidant, antidiabetic, anti-cholesterol, and anti-cardiovascular effects.

The literature selection and study synthesis were based on an assessment of the efficacy of CGA in prior research, in which researchers established strict inclusion and exclusion criteria to isolate the compound's actual physiological impact, in accordance with the standard methodology for thorough pharmacological reviews of CGA. Peer-reviewed, primary experimental study designs that were clearly classified as in vitro (cell lines), in vivo (animal models), and clinical trials (human cohorts) were among the inclusion criteria (Lu et al., 2020; Nguyen et al., 2024).

Additionally, studies concentrating on purified chlorogenic acid, its major isomers (such as 5-CQA), or standardized extracts (such as green coffee bean extract), in which the dose of CGA is specifically extracted and quantified, were required to ensure intervention specificity. Following that, outcome measurements revealed trials with distinct, measurable objectives (Grujić-Letić et al., 2015).

Combining in vitro, in vivo, and clinical trial studies of research is necessary to build a cohesive translational framework for how a compound operates from the microscopic level to human biology. **In vitro** (cellular level) studies, such as cell-line studies, allow researchers to observe raw cellular interactions without systemic interference. It answered how precise molecular pathways, such as how CGA downregulates lipid biosynthesis genes or acts as an anti-inflammatory agent. **In vivo** (animal models) studies evaluate systemic dynamics, where live animal models introduce biological complexity (metabolism, digestion, organ interaction). They allow researchers to study pharmacokinetics, identify safe dosage ranges, and observe tissue-specific efficacy (like hepatic glucose regulation in diabetic mice) that cannot be simulated in a petri dish. **Clinical trials** (human cohorts) are named with verifying real or world efficacy. Human trials establish clinical relevance. Because animals and cells metabolize polyphenols differently than humans, human trials confirm whether the molecular actions observed in the lab actually translate into reproducible health benefits (such as safely reducing blood pressure or visceral fat) despite human bioavailability limitations (Lu et al., 2020; Narayanaperumal et al., 2022; Nikpayam et al., 2020; Volz et al., 2012).

3. RESULTS AND DISCUSSIONS

Anti-Inflammatory Activity

Experimental data represented the concurrent presence of poor quality ongoing aggravation and oxidative pressure in numerous constant illnesses like diabetic complications, cardiovascular and neurodegenerative diseases, alcoholic liver illness, and chronic kidney illness. Irritation is a complex physiological response to tissue injury brought about by exogenous or endogenous sources (Liang & Kitts, 2015).

Anti-obesity activity

Creature studies looking at the impact of green coffee extract (GCE) on body weight showed clashing outcomes. Besides, the impact of GCE on serum lipid profile was recently found in rodents directed moderately high dosages of GCE or CGA(Choi et al., 2016). Low portion GCE beneficially affects body weight and brings down overall serum cholesterol, fatty oil, LDL, and TNF-α levels in high-fat eating routine initiated stout rodents (Ilmiawati et al., 2020).

Antioxidant Activity

Coffee represents one of the most important dietary sources of antioxidant compounds for many populations worldwide (Farah & de Paula Lima, 2019; Torres & Farah, 2017). This contribution is largely attributed to its high content of chlorogenic acids (CGAs) and chlorogenic acid lactones, combined with the widespread consumption of coffee beverages.

The antioxidant properties of CGAs have been extensively investigated through chemical assays, cell culture experiments, and animal studies. Experimental evidence has demonstrated that CGAs can inhibit the oxidation of low-density lipoproteins (LDL) induced by various pro-oxidant agents and can reduce oxidative damage to DNA under in vitro conditions. Among the chlorogenic acids present in coffee, 5-caffeoylquinic acid (5-CQA) is the predominant form and has exhibited strong free-radical scavenging activity. This compound has been reported to neutralize several reactive species, including 1,1-diphenyl-2-picrylhydrazyl (DPPH) radicals, superoxide anions (O_2^-), hydroxyl radicals (•OH), and peroxynitrite ($ONOO^-$). Furthermore, numerous studies have shown its ability to protect DNA molecules from oxidative stress-induced damage (Liang & Kitts, 2015).

Caffeic acid, which is one of the principal metabolites generated from CGA metabolism, together with other phenolic derivatives, has also demonstrated considerable antioxidant capacity (Khan et al., 2016; Marković & Tošović, 2016). In addition, in vitro investigations have revealed that CGAs may enhance cellular resistance to oxidative stress and exert protective effects against oxidation triggered by tumor necrosis factor-alpha (TNF-α), a cytokine closely associated with inflammatory and pathological processes (Amigoni et al., 2017).

Antidiabetic Activity

Shown that three months of supplementation of CGA prompts a huge decrease in TC, and just four of the multitude of studies have tracked down a huge decrease in TG. 90 days of supplementation of 1200
mg CGA in patients with debilitated glucose resistance showed a prominent decrease in TG serum levels (Zuniga et al., 2018).

Antihyperlipidemic Activity

Dyslipidemia and impaired glucose tolerance (IGT) are recognized as major metabolic abnormalities that contribute significantly to the onset and progression of cardiovascular diseases (CVDs) and type 2 diabetes mellitus (Abdul-Ghani et al., 2016). Current clinical recommendations emphasize dietary modification as the first-line approach for managing lipid disorders and disturbances in glucose metabolism. However, the effectiveness of dietary interventions alone has generally been limited, resulting in only modest improvements in metabolic outcomes (DiNicolantonio et al., 2016). Chlorogenic acid (CGA) is a naturally occurring polyphenolic compound formed through the esterification of caffeic acid and quinic acid and belongs to the hydroxycinnamic acid family (Tajik et al., 2017). Growing evidence suggests that CGA possesses beneficial effects on lipid and glucose metabolism. Experimental studies conducted in animal models have demonstrated both antihyperlipidemic and antidiabetic activities of this compound. Nevertheless, findings from human clinical investigations remain inconsistent, and further studies are required to clarify their therapeutic efficacy in humans (Amirian & Fazilat-Pour, 2016).

GCE and its CGA showed hypo-lipidemic consequences for serum levels of triglyceride (TG) and all-out cholesterol (TC) in patients with IGT (Zuniga et al., 2018), and those with non-alcoholic fatty liver infection (Shahmohammadi et al., 2017).

Be that as it may, the consequences for high-thickness lipoprotein (HDL) and low-thickness lipoprotein (LDL) were conflicting. A few investigations showed a huge expansion in serum HDL following GCE consumption (Aghaei et al., 2018; Haidari et al., 2017), while others couldn't find any critical outcomes (Martínez-López et al., 2019; Roshan et al., 2018). Thinking about insulin opposition, fasting blood glucose (FBG) or serum insulin fundamentally decreased after GCE organization in certain examinations. However, no critical changes were seen in some others (Suzuki et al., 2019).

Cardioprotective Activity

A helpful impact of green espresso utilization on glycemic lists and cardio-metabolic danger factors in grown-ups (Morvaridi et al., 2020), yet no huge impact of charged/decaffeinated coffee utilization on insulin levels. They presumed that clinical studies with a longer intervention are more

likely to explain the expected impacts of coffee (Kondo et al., 2018). Various discoveries may be clarified by various handling strategies utilized for the preparation of coffee. In an orderly audit, the researchers announced that the kind of coffee and the techniques for planning are significant for the impact of coffee. utilization on serum levels of lipoproteins (Penson et al., 2018).

Safe Dosage and Consumption Limits

Adequate consumption of green coffee extract (GCE) has been associated with improvements in lipid metabolism and serum lipid profiles. Dose–response analyses have indicated a significant increase in high-density lipoprotein (HDL) concentrations when chlorogenic acid (CGA) intake exceeds 100 mg/day. In contrast, the relationship between CGA dosage and serum triglyceride (TG) levels appears to be nonlinear. Although CGA supplementation may contribute to TG reduction, this effect tends to diminish at doses of 500 mg/day or higher. Similar dose-dependent effects of green coffee supplementation on lipid-related parameters have also been reported in previous meta-analyses of randomized controlled trials (RCTs) (Ding et al., 2020).

Despite the potential metabolic benefits of CGA, supplementation above 500 mg/day is generally not recommended. Excessive intake may increase circulating homocysteine concentrations, a recognized cardiovascular risk factor. Furthermore, higher CGA consumption has been linked to enhanced adrenaline release, which may influence cardiovascular function by elevating heart rate and reducing insulin sensitivity (Turnbull et al., 2017).

The association between coffee consumption and cardiovascular health has remained a topic of scientific debate for many years. Evidence from meta-analytic studies suggests that GCE supplementation can significantly reduce fasting blood glucose (FBG) levels (WMD: −2.35 mg/dL; 95% CI: −3.78 to −0.92; P = 0.001) as well as serum insulin concentrations (WMD: −0.63 μU/L; 95% CI: −1.11 to −0.15; P = 0.01). In addition, a significant reduction in total cholesterol (TC) levels has been observed following GCE administration (WMD: −4.51 mg/dL; 95% CI: −8.39 to −0.64; P = 0.02). The risk of cardiovascular illnesses has been debated for a long time. Decreasing impact of GCE supplementation on FBG (weighted mean difference (WMD): - 2.35, 95% CI: – 3.78, – 0.92 mg/dl, P = 0.001) and serum insulin (WMD: - 0.63, 95% CI: – 1.11, – 0.15 μU/L, P = 0.01). A huge decrease was observed in serum levels of TC following GCE supplementation in the generally speaking meta-examination (WMD: - 4.51, 95% CI: -8.39, -0.64, P = 0.02). Subgroup investigation showed a critical decrease in serum fatty oil; likewise, a huge decrease was found in serum levels of LDL and HDL when the examinations were limited to studies with an intervention term of ≥8 weeks, and those included female subjects. The impacts of chlorogenic acid (CGA) dose, the principal polyphenol in GCE, on FBG, TG, and HDL were in nonlinear designs. Subgroup analyses further demonstrated favorable effects on triglyceride concentrations. Significant changes in low-density lipoprotein (LDL) and HDL levels were also reported in studies involving intervention periods of at least eight weeks and in trials conducted exclusively among female participants. Moreover, the influence of CGA dosage on FBG, TG, and HDL concentrations was characterized by nonlinear dose–response patterns, suggesting that the metabolic effects of CGA may vary according to the amount consumed rather than increasing proportionally with higher doses (Asbaghi et al., 2020).

The mechanism by which CGA lowers cholesterol & triglycerides is: a) Activates AMPK: Acts as a metabolic switch that shifts the body from fat synthesis to fat burning (Zheng et al., 2026); b) Inhibits Synthesis: Blocks SREBP-1c and SREBP-2, shutting down key enzymes responsible for making triglycerides (FAS) and cholesterol (HMG-CoA reductase) (Sun et al., 2024); c) Promotes Oxidation: Increases PPARα expression to accelerate the breakdown and clearance of circulating triglycerides (Sun et al., 2024).

LDL & HDL Results Vary in Humans are caused by: a) Extracts vs. Pure CGA: Many trials use whole extracts containing diterpenes (like cafestol), which actively raise LDL, masking CGA's benefits (Yusni et al., 2026); b) Microbiota & Bioavailability: CGA absorption relies heavily on highly individual gut bacteria to break it down into active metabolites (Kuzia et al., 2025); c) Baseline Health: Healthy cohorts experience minimal fluctuation due to natural homeostasis, whereas

significant improvements are usually restricted to dyslipidemic or diabetic populations (Surma et al., 2023).

Chlorogenic acid (CGA) protects DNA from oxidative damage primarily through two complementary pathways: direct radical scavenging and indirect cellular signaling activation: a) Direct Free Radical Scavenging: Because CGA possesses phenolic hydroxyl groups, it acts as a strong reducing agent. It is highly efficient at capturing and neutralizing reactive oxygen species (ROS)—such as hydrogen peroxide, hydroxyl radicals, and oxygen free radicals—before they can attack double-stranded DNA and cause nucleotide modifications or strand breakage (Tang & Liu, 2008; Wang et al., 2016; Yin et al., 2022). Kinetic studies show that CGA physically traps these propagating radicals primarily by reducing them rather than just donating hydrogen atoms (Tang & Liu, 2008); b) Activation of Endogenous Antioxidant Defenses (The Nrf2 Pathway): Beyond direct biochemical neutralization, CGA serves as a signaling modulator within the cell. It triggers the Nrf2 (NF-E2-related factor 2) transcription pathway (Yin et al., 2022). Once activated, Nrf2 translocates to the cell nucleus and upregulates the expression of essential internal antioxidant enzymes, such as superoxide dismutase (SOD), glutathione peroxidase (GSH-Px), and catalase (CAT).

This enzymatic boost reinforces the cell's long-term capability to prevent internal oxidative stress and significantly reduces the occurrence of radiation- or chemical-induced genotoxicity and DNA lesion accumulation (Yin et al., 2022).

4. CONCLUSION

Based on this study, it can be concluded that CGA is the major polyphenolic compound in green coffee and has been widely recognized for its potential health-promoting properties. Evidence from in vitro, in vivo, and clinical studies suggests that CGA is able to be used for the prevention of metabolic disease and exhibits antioxidant, cardioprotective, antihyperlipidemic, antidiabetic, anti-inflammatory, anticancer, and anti-obesity activities, largely through its modulation of oxidative stress and cellular defense pathways. Among the major classes of chlorogenic acids, caffeoylquinic acids (CQAs) are the most abundant and generally more stable than dicaffeoylquinic acids (diCQAs). However, the stability and bioactivity of CGA derivatives may be affected by processing conditions, particularly heat, which can induce isomerization and degradation reactions. The prospects are highly promising, driven by CGA from green coffee focused on preventive healthcare. Key avenues and development focus areas include expanding health targets, advanced standardization, and overcoming technical hurdles. Overall, green coffee and its principal bioactive constituent, CGA, show considerable potential for supporting metabolic and cardiovascular health. Nevertheless, excessive intake should be avoided, as high doses may increase homocysteine levels and adversely affect cardiovascular and metabolic functions. Further well-designed human studies are needed to determine the optimal dosage, safety, and long-term efficacy of CGA supplementation.

REFERENCES

Abdul-Ghani, M., DeFronzo, R. A., & Jayyousi, A. (2016). Prediabetes and risk of diabetes and associated complications: impaired fasting glucose versus impaired glucose tolerance: does it matter? *Current Opinion in Clinical Nutrition & Metabolic Care*, *19*(5), 394–399.

Aghaei, F., Shadmehri, S., & Darvishvand, Z. P. (2018). Report of Health Care Original Article. *Health Care*, *4*(2), 38–46.

Amigoni, L., Stuknytė, M., Ciaramelli, C., Magoni, C., Bruni, I., De Noni, I., Airoldi, C., Regonesi, M. E., & Palmioli, A. (2017). Green coffee extract enhances oxidative stress resistance and delays aging in Caenorhabditis elegans. *Journal of Functional Foods*, *33*, 297–306.

Amirian, M.-E., & Fazilat-Pour, M. (2016). Simple and multivariate relationships between spiritual intelligence with general health and happiness. *Journal of Religion and Health*, *55*(4), 1275–1288.

Asbaghi, O., Sadeghian, M., Nasiri, M., Khodadost, M., Shokri, A., Panahande, B., Pirouzi, A., & Sadeghi, O. (2020). The effects of green coffee extract supplementation on glycemic indices and lipid profile in adults: a systematic review and dose-response meta-analysis of clinical trials. *Nutrition Journal*, *19*(1), 71.

Badan Pengawas Obat dan Makanan. (2023). Peraturan Badan Pengawas Obat dan Makanan Nomor 24 Tahun 2023 tentang Persyaratan Keamanan dan Mutu Suplemen Kesehatan. *Badan Pengawas Obat Dan Makanan Republik Indonesia*, 1–36.

Dawidowicz, A. L., & Typek, R. (2017). Transformation of chlorogenic acids during the coffee beans roasting process. *European Food Research and Technology*, *243*(3), 379–390.

Ding, F., Ma, B., Nazary-Vannani, A., Kord-Varkaneh, H., Fatahi, S., Papageorgiou, M., Rahmani, J., Poursoleiman, F., do Nascimento, I. J. B., & Li, H. (2020). The effects of green coffee bean extract supplementation on lipid profile in humans: a systematic review and meta-analysis of randomized controlled trials. *Nutrition, Metabolism and Cardiovascular Diseases*, *30*(1), 1–10.

Farah, A., & de Paula Lima, J. (2019). Consumption of chlorogenic acids through coffee and health implications. *Beverages*, *5*(1), 11.

Gil, M., & Wianowska, D. (2017). Chlorogenic acids–their properties, occurrence and analysis. *Annales Universitatis Mariae Curie-Skłodowska, Sectio AA–Chemia*, *72*(1).

Gonthier, M.-P., Verny, M.-A., Besson, C., Remesy, C., & Scalbert, A. (2003). Chlorogenic acid bioavailability largely depends on its metabolism by the gut microflora in rats. *The Journal of Nutrition*, *133*(6), 1853–1859.

Grujić-Letić, N., Rakić, B., Šefer, E., Rakić, D., Nedeljković, I., Kladar, N., & Božin, B. (2015). Determination of 5-caffeoylquinic acid (5-CQA) as one of the major classes of chlorogenic acid in commercial tea and coffee samples. *Vojnosanitetski Pregled: Military Medical & Pharmaceutical Journal of Serbia*, *72*(11), 1018.

Haidari, F., Samadi, M., Mohammadshahi, M., Jalali, M. T., & Engali, K. A. (2017). Energy restriction combined with green coffee bean extract affects serum adipocytokines and the body composition in obese women. *Asia Pacific Journal of Clinical Nutrition*, *26*(6), 1048–1054.

Ilmiawati, C., Fitri, F., Rofinda, Z. D., & Reza, M. (2020). Green coffee extract modifies body weight, serum lipids and TNF-α in high-fat diet-induced obese rats. *BMC Research Notes*, *13*(1), 208.

Khan, F. A., Maalik, A., & Murtaza, G. (2016). Inhibitory mechanism against oxidative stress of caffeic acid. *Journal of Food and Drug Analysis*, *24*(4), 695–702.

Kondo, Y., Goto, A., Noma, H., Iso, H., Hayashi, K., & Noda, M. (2018). Effects of coffee and tea consumption on glucose metabolism: a systematic review and network meta-analysis. *Nutrients*, *11*(1), 48.

Król, K., Gantner, M., Tatarak, A., & Hallmann, E. (2020). The content of polyphenols in coffee beans as roasting, origin and storage effect. *European Food Research and Technology*, *246*(1), 33–39.

Kuzia, N., Ksepka, N., Fernandez, P. M., Poznański, P., Karczewski, J., Wijas, B., Siwiec, D., Petrykowski, S., & Jóźwik, A. (2025). Therapeutic potential of chlorogenic acid in age-associated metabolic and neurodegenerative disorders. *Animal Science Papers and Reports*, *43*(4), 405–428.

Liang, N., & Kitts, D. D. (2015). Role of chlorogenic acids in controlling oxidative and inflammatory stress conditions. *Nutrients*, *8*(1), 16.

Lu, H., Tian, Z., Cui, Y., Liu, Z., & Ma, X. (2020). Chlorogenic acid: A comprehensive review of the dietary sources, processing effects, bioavailability, beneficial properties, mechanisms of action, and future directions. *Comprehensive Reviews in Food Science and Food Safety*, *19*(6), 3130–3158.

Marković, S., & Tošović, J. (2016). Comparative study of the antioxidative activities of caffeoylquinic and caffeic acids. *Food Chemistry*, *210*, 585–592.

Morvaridi, M., Rayyani, E., Jaafari, M., Khiabani, A., & Rahimlou, M. (2020). The effect of green coffee extract supplementation on cardio metabolic risk factors: a systematic review and meta-analysis of randomized controlled trials. *Journal of Diabetes & Metabolic Disorders*, *19*(1), 645–660.

Narayanaperumal, J., D'souza, A., Miriyala, A., Sharma, B., & Gopal, G. (2022). A randomized double blinded placebo controlled clinical trial for the evaluation of green coffee extract on immune health in healthy adults. *Journal of Traditional and Complementary Medicine*, *12*(5), 455–465.

Nguyen, V., Taine, E. G., Meng, D., Cui, T., & Tan, W. (2024). Chlorogenic acid: A systematic review on the biological functions, mechanistic actions, and therapeutic potentials. *Nutrients*, *16*(7), 924.

Nikpayam, O., Faghfouri, A. H., Tavakoli-Rouzbehani, O. M., Jalali, S.-M., Najafi, M., & Sohrab, G. (2020). The effect of green coffee extract supplementation on lipid profile: A systematic review of clinical trial and in-vivo studies. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews*, *14*(5), 1521–1528.

Penson, P., Serban, M.-C., Ursoniu, S., & Banach, M. (2018). Lipid and Blood Pressure Meta-analysis Collaboration (LBPMC) Group. *Does Coffee Consumption Alter Plasma Lipoprotein (a) Concentrations*, 1706–1714.

Pimpley, V., Patil, S., Srinivasan, K., Desai, N., & Murthy, P. S. (2020). The chemistry of chlorogenic acid from green coffee and its role in attenuation of obesity and diabetes. *Preparative Biochemistry & Biotechnology*, *50*(10), 969–978.

Roshan, H., Nikpayam, O., Sedaghat, M., & Sohrab, G. (2018). Effects of green coffee extract supplementation on anthropometric indices, glycaemic control, blood pressure, lipid profile, insulin resistance and appetite in patients with the metabolic syndrome: a randomised clinical trial. *British Journal of Nutrition*, *119*(3), 250–258.

Shahmohammadi, H. A., Hosseini, S. A., Hajiani, E., Malehi, A. S., & Alipour, M. (2017). Effects of green coffee bean extract supplementation on patients with non-alcoholic fatty liver disease: a randomized clinical trial. *Hepatitis Monthly*, *17*(4).

Singh, B., Bodla, R. B., Kumar, A., & Khatri, M. (2020). Green Coffee in Pharmaceutical Industry: A Boon To Mankind. *Int. J. Innov. Sci. Eng. Technol*, *7*, 149–165.

Sun, M., Zhang, Z., Xie, J., Yu, J., Xiong, S., Xiang, F., Ma, X., Yang, C., & Lin, L. (2024). Research progress on the mechanism for improving glucose and lipid metabolism disorders using phenolic acid components from medicinal and edible homologous plants. *Molecules*, *29*(20), 4790.

Surma, S., Romańczyk, M., Zembala, M. O., & Filipiak, K. J. (2023). Coffee and lipid profile: from theory to everyday practice. *Folia Cardiologica*, *18*(1).

Suzuki, A., Nomura, T., Jokura, H., Kitamura, N., Saiki, A., & Fujii, A. (2019). Chlorogenic acid-enriched green coffee bean extract affects arterial stiffness assessed by the cardio-ankle vascular index in healthy men: a pilot study. *International Journal of Food Sciences and Nutrition*, *70*(7), 901–908.

Tajik, N., Tajik, M., Mack, I., & Enck, P. (2017). The potential effects of chlorogenic acid, the main phenolic components in coffee, on health: a comprehensive review of the literature. *European Journal of Nutrition*, *56*(7), 2215–2244.

Tang, Y.-Z., & Liu, Z.-Q. (2008). Chemical kinetic behavior of chlorogenic acid in protecting erythrocyte and DNA against radical-induced oxidation. *Journal of Agricultural and Food Chemistry*, *56*(22), 11025–11029.

Torres, T., & Farah, A. (2017). Coffee, maté, açaí and beans are the main contributors to the antioxidant capacity of Brazilian's diet. *European Journal of Nutrition*, *56*(4), 1523–1533.

Turnbull, D., Rodricks, J. V, Mariano, G. F., & Chowdhury, F. (2017). Caffeine and cardiovascular health. *Regulatory Toxicology and Pharmacology*, *89*, 165–185.

Volz, N., Boettler, U., Winkler, S., Teller, N., Schwarz, C., Bakuradze, T., Eisenbrand, G., Haupt, L., Griffiths, L. R., & Stiebitz, H. (2012). Effect of coffee combining green coffee bean constituents with typical roasting products on the Nrf2/ARE pathway in vitro and in vivo. *Journal of Agricultural and Food Chemistry*, *60*(38), 9631–9641.

Wang, J., Li, J., Liu, J., Xu, M., Tong, X., & Wang, J. (2016). Chlorogenic acid prevents isoproterenol-induced DNA damage in vascular smooth muscle cells. *Molecular Medicine Reports*, *14*(5), 4063–4068.

Xue, M., Shi, H., Zhang, J., Liu, Q.-Q., Guan, J., Zhang, J.-Y., & Ma, Q. (2016). Stability and degradation of caffeoylquinic acids under different storage conditions studied by high-performance liquid chromatography with photo diode array detection and high-performance liquid chromatography with electrospray ionization collision-induced dissociation tandem mass spectrometry. *Molecules*, *21*(7), 948.

Yin, X., He, X., Wu, L., Yan, D., & Yan, S. (2022). Chlorogenic Acid, the Main Antioxidant in Coffee, Reduces Radiation-Induced Apoptosis and DNA Damage via NF-E2-Related Factor 2 (Nrf2) Activation in Hepatocellular Carcinoma. *Oxidative Medicine and Cellular Longevity*, *2022*(1), 4566949.

Yusni, Y., Yusuf, H., Murzalina, C., & Mahmudati, N. (2026). Synergistic Modulation of Lipid Levels by Coffee and Swimming With Evidence of a Strong Obesity–Dyslipidemia Link: A Preclinical Study. *International Journal of Food Science*, *2026*(1), 8436448.

Zalewska, K., Kulawik, M., Gierszewska, J., Gramala, Z., Kalus, O., Karpiński, M., Maćkowiak, J., Staniewski, A., Szymańska, Z., & Zalewska, B. (2025). Chlorogenic acid's role in metabolic health: Mechanisms and therapeutic potential. *Nutrients*, *17*(20), 3303.

Zheng, B., Xiao, X., Wang, Y., Bai, D., Zhen, W., Guo, F., Zhang, B., Zhang, Y., & Ma, Y. (2026). The Potential of Chlorogenic Acid in Regulating Oxidative Damage, Lipid Metabolism, and Inflammation in Chickens: A Comprehensive Review. *Veterinary Sciences*, *13*(3), 267.

Zuniga, L. Y., Aceves-de la Mora, M. C. A., González-Ortiz, M., Ramos-Núñez, J. L., & Martínez-Abundis, E. (2018). Effect of chlorogenic acid administration on glycemic control, insulin secretion, and insulin sensitivity in patients with impaired glucose tolerance. *Journal of Medicinal Food*, *21*(5), 469–473.