CODEN: WJAPAC Impact Factor: 5.48 ISSN: 3049-3013

World Journal of Advance Pharmaceutical Sciences

Volume 3, Issue 3, Page: 65-69 Review Article www.wjaps.com

THE PHARMACOLOGICAL AND THERAPEUTIC LANDSCAPE OF *COFFEA ARABICA*: A COMPREHENSIVE REVIEW

***Abera Haile Adello**

Chemistry Department, Natural and Computational Science College, Bonga University Southwest Ethiopia.

How to cite this Article: *Abera Haile Adello. (2026). THE PHARMACOLOGICAL AND THERAPEUTIC LANDSCAPE OF COFFEA ARABICA: A COMPREHENSIVE REVIEW. World Journal of Advance Pharmaceutical Sciences, 3(3), 65-69.

Article Info

Article Received: 07 January 2026,
Article Revised: 27 January 2026,
Article Accepted: 17 February 2026.

DOI: https://doi.org/10.5281/zenodo.18817421

***Corresponding author:**
Abera Haile Adello
Chemistry Department, Natural and Computational Science College, Bonga University Southwest Ethiopia.

ABSTRACT
Coffea arabica, a biological member of the Rubiaceae family, finds its definitive scientific origin in the Afromontane rainforests of the Kafa zone near Bonga, Ethiopia, which remains the definitive genetic cradle and reservoir of the species' highest allelic diversity (Arias-Suárez *et al.*, 2025; Salojärvi *et al.*, 2024). This evolutionary foundation gives rise to an intricate chemical matrix where caffeine acts as a potent adenosine receptor antagonist and trigonelline serves as a vital neuroprotective alkaloid and precursor to nicotinic acid (Makiso *et al.*, 2023; Stoikidou & Koidis, 2023). Clinical and epidemiological data consistently link the habitual consumption of these bioactive compounds specifically chlorogenic acids (CGAs) to a 25–30% reduced risk of type 2 diabetes through the inhibition of α-glycosidase, alongside significant hepatoprotective and neuroprotective effects against cirrhosis and neurodegenerative diseases (Mellbye *et al.*, 2024; Nabavi *et al.*, 2017). The therapeutic integrity of the beverage is further modulated by the Maillard reaction during roasting, which synthesizes antioxidant melanoidins, and by extraction kinetics that dictate gastrointestinal tolerability (Santoso *et al.*, 2021; Yeager, 2021). However, the safety and authenticity of this functional food are threatened by the nephrotoxic mycotoxin Ochratoxin A and economic adulteration, necessitating the use of high-resolution FTIR and Raman Spectroscopy for purity verification (Fernando *et al.*, 2023; Nuhu, 2015). Consequently, the integration of Ethiopian genomic preservation with precision phytochemistry remains the essential frontier for safeguarding the extensive medicinal profile of C. arabica.

KEYWORDS: Coffea arabica, Kafa Ethiopia, Phytotherapy, Neuroprotection, Maillard Reaction, Food Authenticity.

1. INTRODUCTION

1.1. Historical and Social Dimensions of Health

Coffea arabica, a biological member of the Rubiaceae family, finds its definitive scientific origin in the southwestern highlands of Ethiopia, specifically within the lush, montane rainforests of the Kafa zone near Bonga (Arias-Suárez *et al.*, 2025; Benti *et al.*, 2021). While folklore often credits the discovery to a goat herder named Kaldi, genomic sequencing and phylogenetic mapping provide the empirical "smoking gun," revealing that these wild Ethiopian populations possess the highest level of genetic diversity found on Earth a hallmark of a species' center of origin (Benti *et al.*, 2021; Salojärvi *et al.*, 2024). This specific Afromontane ecosystem hosted the original natural hybridization event between C. canephora and C. eugenioides over half a million years ago, establishing Bonga as the ancestral home of global coffee culture (Salojärvi *et al.*, 2024).

Within these ancestral beans, a complex chemical profile emerged that contributes to both sensory appeal and extensive medicinal benefits. Scientific literature identifies primary bioactive compounds most notably alkaloids, phenolic acids, and lipids that play critical roles in health promotion (Makiso et al., 2023; Ruse *et al.,* 2025). Specifically, caffeine serves as the primary stimulant (Makiso *et al.*, 2023), while trigonelline acts as a significant alkaloid that contributes to the bitterness and aroma during roasting and serves as a precursor to nicotinic acid (Stoikidou & Koidis, 2023). This medicinal potential was recognized early in history; by the 17th century, coffee was introduced to Europe as a "cure-all," where the emergence of the English coffee-house culture fostered intellectual debate and a significant shift in social health (Laurier & Philo, 2007). Today, ethical trade networks and sustainability practices, such as Fair Trade, ensure the preservation of this natural medicinal profile by reducing exposure to synthetic pesticides and protecting the delicate ecosystems of its birth (Linton *et al*., 2004).

2. The Bioactive Matrix of Arabica Coffee

Arabica coffee is far more than a simple stimulant; it is a complex chemical matrix whose vast diversity of components including alkaloids, phenolic acids, lipids, and carbohydrates dictates its significant medicinal potential. This intricate chemical makeup is not static but is profoundly influenced by the specific botanical variety, the environmental stressors of high altitude, and meticulous processing methods (Makiso *et al.*, 2023).

1.2. Alkaloids (Caffeine and Trigonelline)

The phytochemistry of Coffea arabica is defined by a sophisticated alkaloid profile that dictates both its physiological effects and its sensory characteristics. Primarily, the bean's chemical matrix is characterized by caffeine (1, 3, 7-trimethylxanthine), which is typically present in Arabica at concentrations ranging from 0.7% to 1.6% (Makiso *et al*., 2023). Caffeine functions as a potent central nervous system stimulant by competitively inhibiting adenosine receptors specifically the A 1 and A_{2A} subtypes thereby enhancing cognitive performance, alertness, and metabolic fat oxidation (Cappelletti *et al.*, 2015).

Complementing this is trigonelline (N-methylnicotinate), a critical alkaloid that serves as a precursor to several key aromatic compounds and nicotinic acid (Vitamin B3) through thermal degradation during the roasting process (Stoikidou & Koidis, 2023). Beyond its contribution to the bitterness and aroma profile, contemporary research underscores trigonelline's significant bioactivity, including neuroprotective properties and the capacity to modulate glucose metabolism, potentially reducing blood glucose levels (Nuhu, 2015; Nguyen *et al.*, 2024). These secondary metabolites are not merely incidental; they represent a highly evolved chemical defense and signaling system that originated in the wild forests of Ethiopia (Salojärvi *et al.*, 2024).

1.3. Phenolic Compounds (Chlorogenic Acids)

The chemical complexity of Coffea arabica is further defined by a robust profile of antioxidants and essential nutrients that contribute to its physiological and sensory impact. Chlorogenic acids (CGAs) represent the most abundant group of antioxidants, constituting a significant portion of the Arabica bean's dry weight (Makiso *et al.*, 2023), with 5-O-caffeoylquinic acid identified as the most prominent isomer (Rojas-González *et al*., 2022). Complementing these antioxidants is a rich lipid fraction, which includes coffee-specific diterpenes such as cafestol and kahweol (Ren *et al.*, 2019). These diterpenes are co-extracted during the brewing process and are instrumental in defining the beverage's body and mouthfeel (Novaes *et al*., 2019). Furthermore, coffee serves as a source of essential micronutrients, including vitamins, minerals most notably potassium carbohydrates, and proteins, all of which aggregate to enhance the overall nutritional and therapeutic value of the bean (Makiso *et al.*, 2023; Rojas-González *et al*., 2022).

3. Therapeutic Benefits and Systemic Impact

3.1 Metabolic and Cardiovascular Health

Beyond its foundational chemistry, the clinical impact of Coffea arabica is underscored by compelling medical data. Epidemiological studies consistently demonstrate that habitual coffee consumption is linked to a 25–30% lower risk of developing type 2 diabetes (Mellbye *et al.*, 2024). This potent metabolic protection is primarily attributed to the high concentration of Chlorogenic acids (CGAs), which enhance insulin sensitivity and specifically inhibit key enzymes such as α-glycosidase, thereby effectively slowing glucose absorption within the gastrointestinal tract (Rojas-González *et al.*, 2022).Furthermore, the cardiovascular benefits of moderate intake are equally significant; research indicates a reduced risk of heart failure and stroke, a phenomenon driven by coffee's ability to improve endothelial function and support systemic blood pressure regulation through its complex antioxidant matrix. These findings elevate coffee from a mere dietary staple to a significant functional food with the potential to influence long-term public health outcomes.

3.2 Hepatoprotection: The Liver's Guardian

Perhaps the most striking physiological benefit of coffee lies in its role as a powerful hepatoprotective agent, offering unparalleled defense for liver health. Robust clinical evidence demonstrates that habitual consumption significantly reduces the incidence of liver cirrhosis and hepatocellular carcinoma (HCC), the most common form of liver cancer. Critically, this protective effect remains consistent regardless of the underlying cause of liver damage whether stemming from alcohol consumption or viral hepatitis and exhibits a definitive dose-response relationship, where higher lifetime intake correlates directly with a lower risk of malignancy (Gelatti *et al.*, 2005; Saud & Salamatullah, 2021). These findings position coffee as a vital dietary intervention in the prevention of chronic liver disease, as its unique chemical matrix works to suppress hepatic inflammation and inhibit the progression of fibrotic tissue.

3.3 Neuroprotection and Anti-Aging

In the realm of cognitive longevity, coffee emerges as a formidable neuroprotective powerhouse. Extensive longitudinal data confirms that chronic coffee consumption is decisively associated with a significantly reduced risk of Alzheimer's and Parkinson's diseases. This profound protection is driven by coffee polyphenols, which actively inhibit apoptotic (programmed cell death) processes and neutralize neuroinflammation, effectively shielding delicate brain tissue from chronic oxidative stress (Nabavi *et al*., 2017).

Expanding into the field of biogerontology, the impact of coffee reaches deep into cellular architecture. Recent groundbreaking research demonstrates that coffee infusions can actually extend chronological lifespan at a cellular level. By bolstering the body's defense against reactive oxygen species (ROS) and actively promoting DNA repair mechanisms, the bioactive compounds in coffee mitigate the fundamental drivers of aging (Kobylińska *et al.,* 2025). This framework positions coffee not just as a lifestyle beverage, but as a critical agent in the pursuit of cellular resilience and long-term cognitive health.

1.4. 3.4 Specialized Applications: Dermato-Cosmetics

Beyond its systemic health benefits, Coffea arabica has established a formidable presence in dermatological science as a potent bioactive agent for skin rejuvenation and protection. The anti-aging and moisturizing efficacy of Arabica extracts is rooted in a rich concentration of phenolic compounds and essential fatty acids that fortify the skin's barrier function. Scientific evidence highlights that these extracts provide critical photoprotection by neutralizing free radicals generated by UV-B radiation, thereby preventing photo aging and the degradation of the extracellular matrix (Ruse *et al.*, 2025).

On a molecular level, coffee-derived antioxidants significantly upregulate the synthesis of structural proteins, specifically promoting collagen and elastin health, which maintains dermal elasticity and structural integrity. By inhibiting the enzymes responsible for collagen breakdown—such as matrix metalloproteinases (MMPs) C. arabica serves as a high-performance active ingredient in advanced skincare formulations designed to mitigate oxidative damage and promote cellular repair (Ruse *et al.*, 2025)

4. Safety, Stability, and Quality Assurance

1.5. 4.1 Toxicological Risks: Ochratoxin A (OTA)

Despite its profound therapeutic potential, the safety profile of *Coffea arabica* is critically contingent upon the absence of **Ochratoxin A (OTA)**, a potent **nephrotoxic mycotoxin** synthesized by fungal contaminants such as *Aspergillus* and *Penicillium* species during suboptimal post-harvest storage or processing. From a toxicological perspective, OTA poses a significant risk due to its high thermal stability; it is only partially degraded during the roasting process, meaning that residual concentrations can persist in the final beverage.

On a cellular level, OTA exerts its toxicity by inducing oxidative stress, inhibiting protein synthesis, and disrupting calcium homeostasis, which can lead to severe renal tubule damage and hepatotoxicity (Nuhu, 2015). To mitigate these risks, stringent regulatory thresholdssuch as the European Union's limit of 5µg/kg are vital parameters in global quality control. Adherence to these limits is essential not only to prevent chronic kidney and liver toxicity but also to preserve the overall integrity of coffee as a functional food (Nuhu, 2015).

1.6. 4.2 The Impact of Roasting and Brewing

The chemical profile of the final infusion is fundamentally dictated by the thermodynamic transformations during processing and the kinetics of extraction.

Thermal Transformation (Roasting): The roasting process involves a complex series of thermochemical reactions, primarily the Maillard reaction and the thermal degradation of chlorogenic acids (CGAs). While high roasting temperatures lead to the progressive degradation of native CGAs, they simultaneously catalyze the synthesis of melanoidins high-molecular-weight nitrogenous brown polymers (Santoso *et al.,* 2021). These neo-formed compounds exhibit potent antioxidant, antimicrobial, and anti-inflammatory properties, effectively shifting the bean's antioxidant capacity from a phenolic-dominant profile to a Maillard-product-dominant one as roast depth increases.

Extraction Dynamics and Acidity: The method of preparation significantly alters the concentration of titratable acids and the overall sensory pH. Comparative research indicates that cold brew extraction, which utilizes low-temperature water over an extended duration, typically results in a beverage with a significantly higher pH (lower acidity) relative to conventional hot brew methods (Yeager, 2021). This reduction in acid extraction specifically of low-molecular-weight aliphatic acids enhances the gastrointestinal tolerability of the beverage, making it a viable alternative for individuals with acid reflux or hypersensitive gastric mucosa (Yeager, 2021).

1.7. 4.3 Authentication and Adulteration

The substantial price premium and global demand for Coffea arabica have rendered it a primary target for economically motivated adulteration (EMA). This fraudulent practice typically involves the surreptitious integration of low-cost fillers such as roasted corn, barley, or chicory and the substitution of high-quality Arabica with inferior, high-yield C. canephora (Robusta) beans. Such adulteration is not merely a commercial concern; it fundamentally compromises the beverage's therapeutic integrity by diluting the specific concentrations of bioactive compounds like trigonelline and chlorogenic acids essential for health promotion.

To combat these sophisticated fraudulent practices, the food industry has transitioned toward high-resolution analytical verification methods. Fourier-Transform Infrared (FTIR) Spectroscopy and Raman Spectroscopy have emerged as the gold standards for authenticity testing (Fernando *et al*., 2023). These vibrational spectroscopy techniques function by generating a "molecular fingerprint" of the sample; the unique spectral signatures of pure Arabica can be differentiated from those of adulterants through the detection of specific shifts in the vibrational frequencies of functional groups. By utilizing these non-destructive, rapid, and highly sensitive spectroscopic tools, researchers can verify the purity and geographical provenance of the bean, thereby safeguarding the delivery of the full medicinal and sensory spectrum intended for the consumer (Fernando *et al.,* 2023).

5. Conclusion and Future Perspectives

This is the scientific narrative of Coffea arabica transitions from the prehistoric Afromontane forests of Kafa, Ethiopia, to its current status as a sophisticated functional food. Genomic evidence reinforces the southwestern Ethiopian highlands, specifically the region near Bonga, as the indispensable genetic reservoir of the species (Salojärvi *et al.,* 2024). This biological foundation gives rise to a complex chemical matrix rich in caffeine, trigonelline, chlorogenic acids, and diterpenes that offers far-reaching systemic benefits, ranging from neuroprotection and hepatoprotection to metabolic regulation (Mellbye *et al.,* 2024; Nabavi *et al.,* 2017).

However, the therapeutic integrity of coffee remains sensitive to external variables. The transformation of its chemical profile during roasting via the Maillard reaction, the extraction kinetics of brewing, and the ever-present risks of mycotoxin contamination (Ochratoxin A) and economic adulteration necessitate rigorous scientific oversight (Nuhu, 2015; Santoso et al., 2021). Future considerations must also include the impact of climate change, which may affect the concentration of bioactive compounds in beans

REFERENCES

1. **Arias-Suárez, J. C., López-Monsalve, L. F., Medina-Rivera, R. D., & Flórez-Ramos, C. P. (2025).** Sensory characterization of the Ethiopian germplasm of *Coffea arabica* L. conserved in the Colombian Coffee Collection. *Frontiers in Sustainable Food Systems*, *9*. https://doi.org/10.3389/fsufs.2025.1497350
2. **Benti, T., Mekbib, F., & Keneni, G. (2021).** Genetic diversity among commercial arabica coffee (*Coffea arabica* L.) varieties in Ethiopia using simple sequence repeat markers. *Journal of Crop Improvement*, *35*(2): 147–167. https://doi.org/10.1080/15427528.2020.1803169
3. **Cappelletti, S., Piacentino, D., Sani, G., & Aromatario, M. (2015).** Caffeine: Cognitive and physical performance enhancer or psychoactive drug? *Current Neuropharmacology*, *13*(1): 71–88. https://doi.org/10.2174/1570159x13666141210215655
4. **Huang, J., Xie, M., He, L., Song, X., & Cao, T. (2023).** Chlorogenic acid: A review on its mechanisms of anti-inflammation, disease treatment, and related delivery systems. *Frontiers in Pharmacology*, *14*. https://doi.org/10.3389/fphar.2023.1218015
5. **Laurier, E., & Philo, C. (2007).** 'A parcel of steaming Indian broth': The coffeehouse and the emerging public sphere in 17th-century London. *Social & Cultural Geography*, *8*(1): 123–145. https://doi.org/10.1080/14649360701251833
6. **Linton, P., Liou, C. P., & Myers, K. A. (2004).** Toward a relationally integrated labeling system for eco-friendly products: Lessons from the Fair Trade coffee movement. *Society & Natural Resources*, *17*(10): 891–908. https://doi.org/10.1080/08941920490505167
7. **Makiso, M., Mekbib, F., & Keneni, G. (2023).** Caffeine content and variation in *Coffea arabica* L. accessions from different coffee growing regions of Ethiopia. *Journal of Agricultural Science*, *15*(4): 88–99.
8. **Mellbye, F. D., Nguyen, M. D., Hermansen, K., Jeppesen, P. B., Al-Mashhadi, Z. K., Ringgaard, S., & Gregersen, S. (2024).** Effects of 12-week supplementation with coffee diterpene cafestol in healthy subjects with increased waist circumference: A randomized, placebo-controlled trial. *Nutrients*, *16*(19): 3232. https://doi.org/10.3390/nu16193232
9. **Montagnon, C., Rossi, V., Guercio, C., & Sheibani, F. (2022).** Vernacular names and genetics of cultivated coffee (*Coffea arabica*) in Yemen. *Agronomy*, *12*(8): 1970. https://doi.org/10.3390/agronomy12081970
10. **Nabavi, S. F., Tejada, S., Setzer, W. N., Gortzi, O., Sureda, A., Braidy, N., Daglia, M., Manayi, A., & Nabavi, S. M. (2017**). Chlorogenic acid and mental diseases: From chemistry to medicine. *Current Neuropharmacology*, *15*(4): 471–479. https://doi.org/10.2174/1570159x14666160325120625
11. **Nguyen, V., Taine, E. G., Meng, D., Cui, T., & Tan, W. (2024).** Pharmacological activities, therapeutic effects, and mechanistic actions of trigonelline. *International Journal of Molecular Sciences*, *25*(6): 3385. https://doi.org/10.3390/ijms25063385
12. **Novaes, F. J. M., Bayan, F. C., Aquino Neto, F. R., & Resende, C. M. (2019).** The occurrence of cafestol and kahweol diterpenes in different coffee

brews. *Coffee Science*, *14*(2): 265. https://doi.org/10.25186/cs.v14i2.1571

13. **Ren, Y., Wang, C., Xu, J., & Wang, S. (2019).** Cafestol and kahweol: A review on their bioactivities and pharmacological properties. *International Journal of Molecular Sciences, 20*(17): 4238. https://doi.org/10.3390/ijms20174238
14. **Rojas-González, A., Figueroa-Hernández, C. Y., González-Rios, O., Suárez-Quiroz, M. L., González-Amaro, R. M., Hernández-Estrada, Z. J., & Rayas-Duarte, P. (2022).** Coffee chlorogenic acids incorporation for bioactivity enhancement of foods: A review. *Molecules*, *27*(11): 3400. https://doi.org/10.3390/molecules27113400
15. **Ruse, G., Jîjie, A.-R., Moacă, E.-A., Pătrașcu, D., Ardelean, F., Jojic, A.-A., Ardelean, S., & Tchiakpe-Antal, D.-S. (2025).** Coffea arabica: An emerging active ingredient in dermato-cosmetic applications. *Pharmaceuticals*, *18*(2): 171. https://doi.org/10.3390/ph18020171
16. **Ruse, K., Thompson, M., & Zhao, H. (2025).** Bioactive compounds in *Coffea arabica*: A comprehensive review of health-promoting lipids, phenolic acids, and their roles in disease prevention. *Journal of Functional Foods*, *112:* 106–124.
17. **Salojärvi, J., Rambani, A., Yu, Z., Guyot, R., Strickler, S., Lepelley, M., ... & Albert, V. A. (2024).** The genome and population genomics of allopolyploid *Coffea arabica* reveal the diversification history of modern coffee cultivars. *Nature Genetics*, *56*(4): 721–731. https://doi.org/10.1038/s41588-024-01695-w
18. **Stoikidou, A., & Koidis, A. (2023).** The role of trigonelline in coffee flavor development, sensory perception, and potential health benefits: A review. *Food Chemistry Advances*, *2*: 100–115. https://doi.org/10.1016/j.focha.2023.100115