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Global Research Trends on the Role of Chlorogenic Acid on Antidiabetic Mechanisms and Reproductive Hormone Regulation (2015-2025): A Bibliometric Analysis

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Bibliometric Analysis;
Metabolic Regulation

ABSTRACT

Introduction: Chlorogenic acid (CGA) is a natural chemical discovered in a variety of plants that has been associated with numerous health benefits. Recent evidence suggests that CGA impacts reproductive hormone regulation, thus linking metabolic health and endocrine function. Understanding trends and gaps in research at this intersection is crucial. This study characterizes global research patterns, collaboration, and thematic evolution on CGA's antidiabetic activity and its influence on reproductive hormones through bibliometric analysis.

Methods: Data were retrieved from the Scopus database using the keywords ("Chlorogenic Acid") AND ("Antidiabetic") AND ("Reproductive Hormone" OR "Testosterone" OR "LH" OR "FSH" OR "Estrogen" OR "Sperm" OR "Fertility") OR ("Reproductive Hormone" OR "Testosterone" OR "LH" OR "FSH" OR "Estrogen" OR "Sperm" OR "Fertility"). Publications from 2015 to 2025 were included. Bibliometric analysis was performed using VOSviewer and Biblioshiny to visualize co-authorship networks, keyword co-occurrence, publication trends, source dynamics, and thematic clusters.

Results: A total of 162 relevant publications were identified, with a consistent increase observed from 2015 and a peak in 2024. Egypt, China, South Korea, and Saudi Arabia emerged as leading contributors, concentrating research in Asia and the Middle East. The primary journals were Molecules, Nutrients, and Frontiers in Pharmacology. Keyword mapping identified three principal clusters: phytochemical and antioxidant characterization, metabolic and antidiabetic mechanisms, and hormonal and molecular regulation. Thematic analysis revealed a shift from compound characterization to mechanistic and translational studies integrating metabolism and reproductive endocrinology.

Conclusion: Global research increasingly highlights CGA as a bridge between metabolic and hormonal regulation. Our findings show a shift toward interdisciplinary, molecular investigations, but reveal significant gaps in clinical validation and formulation research. Unlocking CGA's therapeutic potential in metabolic and reproductive health will depend on advanced multiomics, enhanced formulations, and greater global research partnerships.

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INTRODUCTION

Metabolic and reproductive disorders such as type 2 diabetes mellitus (T2DM), polycystic ovary syndrome (PCOS), obesity, and hormonal dysregulation are global health challenges. Over the past two decades, these disorders have become interconnected (1). Chronic hyperglycemia and insulin resistance harm glucose metabolism. They disrupt the hypothalamic pituitary gonadal axis, causing ovulatory dysfunction, infertility, and altered steroidogenesis in both males and females (2). Oxidative stress, systemic inflammation, and lifestyle factors such as poor diet and inactivity worsen these conditions (3). Conventional drugs often fail to address the complex causes of these disorders and may cause side effects. This drives interest in natural bioactive compounds with multitarget actions. Understanding the link between metabolic pathways and hormonal regulation is vital in biomedical and nutritional sciences (4,5).

Chlorogenic acid (CGA) is a polyphenolic compound found in coffee, fruits, and medicinal plants (6). It is a promising agent connecting metabolic and reproductive health (7,8). CGA has potent antioxidant, anti-inflammatory, and metabolic regulatory effects (9). It acts through pathways like AMP-activated protein kinase (AMPK), nuclear factor erythroid 2-related factor 2 (Nrf2), and peroxisome proliferator-activated receptor gamma (PPARγ) (10,11). Recent studies show that CGA improves glucose homeostasis, lowers insulin resistance, and modulates lipid metabolism in diabetic models (5,12). CGA may also benefit reproductive function by affecting sex hormone synthesis, promoting follicular development, and reducing oxidative stress in ovarian tissue, especially in PCOS and endocrine dysfunction models. CGA's impact on gut microbiota and metabolic endotoxemia may also affect gonadal hormone secretion. These findings suggest that CGA is key to connecting metabolic regulation and reproductive endocrinology (13).

Despite recent progress, few studies map the research trends linking chlorogenic acid, metabolism, and reproductive hormones. Most current studies focus on CGA's antioxidant or antidiabetic effects and often overlook its role in the endocrine system. No bibliometric analysis has examined collaborative networks or tracked how CGA research themes evolve in metabolism and reproduction. This study analyzes Scopus-indexed literature from 2015 to 2025. It focuses on the overlap between CGA's antidiabetic properties and research on reproductive hormones. The analysis identifies publication patterns, leading countries and institutions, top journals, and new themes. It aims to give a structured overview of current knowledge and future research in phytochemical endocrinology.

Research Objectives

This study comprehensively maps and analyzes global scientific trends in chlorogenic acid (CGA) research. It focuses on CGA's associations with reproductive hormones and antidiabetic activity. Using a bibliometric approach, the study examines Scopus-indexed publications from 2015 to 2025. It identifies patterns in research productivity, leading countries, institutions, journals, and influential authors in this field. The analysis covers keyword co-occurrence networks, author collaborations, and thematic evolution. This demonstrates the progression of CGA research, including the shift from phytochemical characterization to the study of metabolic and hormonal mechanisms. By combining these methods, the study gives a holistic overview of the global CGA research landscape. It identifies knowledge gaps at the intersection of metabolism and reproductive endocrinology and proposes future research directions. The findings support phytochemical and nutraceutical innovations aimed at improving metabolic and reproductive health outcomes.

METHOD

Study Design

A descriptive bibliometric design mapped and analyzed global research trends on Chlorogenic Acid (CGA) in relation to reproductive hormones and antidiabetic activity. Data were collected from Scopus for publications from 2015 to 2025. Boolean search terms included "Chlorogenic Acid", "Antidiabetic", and reproductive hormone-related keywords (Testosterone, Estrogen, LH, FSH, Sperm, Fertility). The dataset was refined using PRISMA 2020 guidelines, yielding 162 eligible publications after screening and deduplication. Bibliometric analyses used VOSviewer (v1.6.20) to map and visualize co-authorship, keyword co-occurrence, and thematic clusters. Biblioshiny (from Bibliometrix R-package v4.1.3) supported performance and trend analysis, including publication growth, source dynamics, and thematic evolution. The study primarily aimed to identify patterns in scientific productivity,

collaboration networks, and thematic development regarding CGA, reproductive hormones, and antidiabetic activity. As typical in bibliometric research, individual study quality was not assessed. The objective was to visualize and interpret research structures, not evaluate methodological rigor or experimental outcomes.

Data Collection

Data were collected from Scopus, a comprehensive source of peer-reviewed literature in the biomedical, pharmacological, and biochemical fields. Scopus was chosen for its rich metadata, such as author affiliations, citations, keywords, and journal metrics, all of which are vital for bibliometric analysis. The search was performed using the following Boolean query ("Chlorogenic Acid") AND ("Antidiabetic") AND ("Reproductive Hormone" OR "Testosterone" OR "LH" OR "FSH" OR "Estrogen" OR "Sperm" OR "Fertility") OR ("Reproductive Hormone" OR "Testosterone" OR "LH" OR "FSH" OR "Estrogen" OR "Sperm" OR "Fertility"). The search included publications from 2015 to 2025, representing the latest decade of output in this area. Only English articles were included; conference proceedings, reviews, book chapters, editorials, and non-peer-reviewed works were excluded. Screening followed the PRISMA 2020 framework for transparency and replicability. Database searches yielded 739 records. Automation tools removed 434 ineligible records, leaving 305 studies for title and abstract screening. Of these, nine were irrelevant, and eight could not be retrieved. This left 288 reports for eligibility assessment. Screening excluded 126 that did not meet the inclusion criteria, resulting in 162 studies in the final bibliometric dataset for analysis.

All bibliographic data were exported in CSV format and analyzed using VOSviewer and Biblioshiny. *VOSviewer* visualized co-authorship networks, keyword co-occurrences, and thematic clusters using the association strength normalization method (minimum keyword occurrence = 5). *Biblioshiny* was used to identify yearly publication trends, citation patterns, and shifting themes over time.

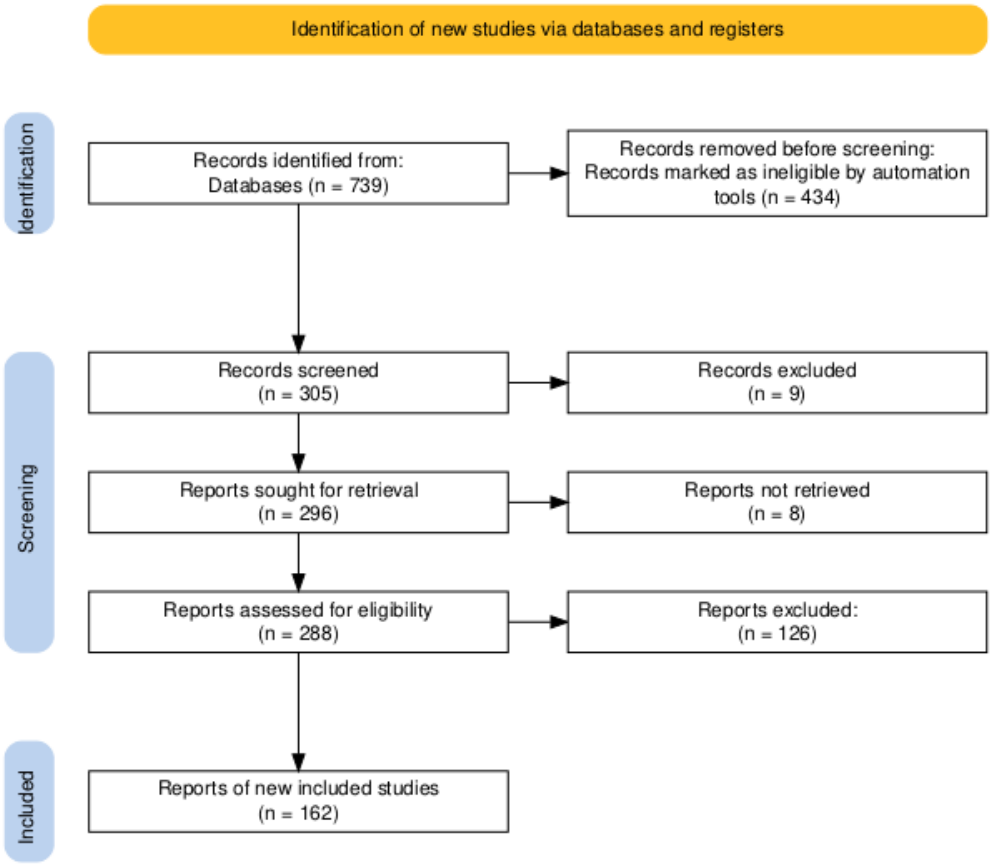


Figure 1. PRISMA Flowchart search process

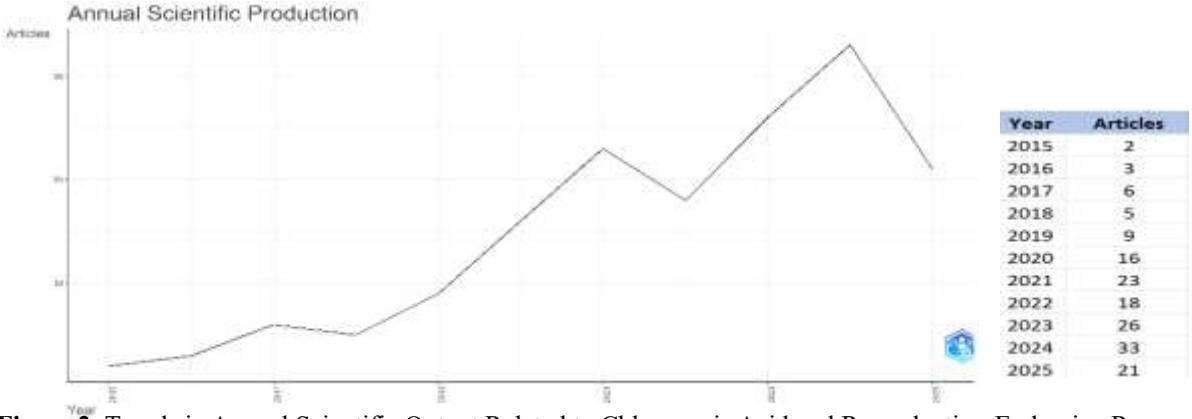
Data Analysis

Bibliographic data were extracted from the Scopus database and exported in CSV format. The dataset was analyzed in Biblioshiny (Bibliometrix R-package, version 4.1.3) for descriptive and performance analyses, including publication trends, citation patterns, and thematic evolution. VOSviewer (version 1.6.20) was used to visualize bibliometric maps of keyword co-occurrence, collaboration patterns, and thematic clusters. Biblioshiny provided quantitative analysis, while VOSviewer highlighted relationships and clusters. Their combined use offered comprehensive insights into global research on chlorogenic acid, supporting an understanding of its scientific evolution in metabolic and reproductive health (14).

RESULTS

Scientific Production

Publication trends from 2015 to 2025 show a clear upward trajectory in research on chlorogenic acid, diabetes, and reproductive hormones. Between 2015 and 2017, publication numbers were low, reflecting limited early exploration. Interest grew around 2018–2019 with more studies on chlorogenic acid's bioactive and hormonal effects. From 2020 to 2024, a substantial increase occurred, peaking in 2024 with over 30 publications. This rise indicates that researchers increasingly view chlorogenic acid as a promising candidate for antidiabetic and reproductive interventions, potentially due to broader scientific shifts and emerging clinical needs. The trend may connect to a global boost in nutraceutical and phytochemical research and a greater focus on metabolic and reproductive health. A slight decline in 2025 likely results from incomplete data or a temporary funding change. Overall, the decade shows steady growth in scholarly output, emphasizing chlorogenic acid's growing relevance for therapeutic and hormonal research. (*Figure 2*)



Year	Articles
2015	2
2016	3
2017	6
2018	5
2019	9
2020	16
2021	23
2022	18
2023	26
2024	33
2025	21

Figure 2. Trends in Annual Scientific Output Related to Chlorogenic Acid and Reproductive-Endocrine Research (2015–2025)

The line graph shows annual publications from 2015 to 2025 on chlorogenic acid, antidiabetic activity, and reproductive hormones, as indexed by Scopus. Publications increased steadily from 2015 to 2019, indicating growing recognition of chlorogenic acid's metabolic and hormonal roles. A sharp rise occurred between 2020 and 2024, peaking at over 30 publications in 2024. This trend matches heightened research into plant-derived compounds for diabetes and reproductive health. The minor in 2025 may reflect incomplete indexing or shifting research priorities. Overall, these patterns underscore sustained global interest in phytochemicals and their effects on endocrine and metabolic regulation.

Country Scientific Production

Figure 3 illustrates the global distribution of scientific publications on chlorogenic acid, antidiabetic activity, and reproductive hormones. Egypt leads with 91 publications, followed by China with 80, South Korea with 39, and Saudi Arabia with 37. Egypt's leading position reflects an active research community focused on the pharmacological and endocrine properties of natural compounds, especially in diabetes and male reproductive dysfunction (15). China ranks second due to its strong interest in phytochemical therapeutics and robust biomedical innovation infrastructure.

South Korea and Saudi Arabia also contribute significantly, demonstrating the rise of excellence centers in metabolic and hormonal phytotherapy (16). These findings reveal a clear geographical trend: Asia and the Middle East are the main hubs of scientific activity in this field, while Western and Latin American countries contribute less (17). This pattern underscores the growing influence of developing nations in advancing natural compound-based interventions for chronic and reproductive health disorders (18).

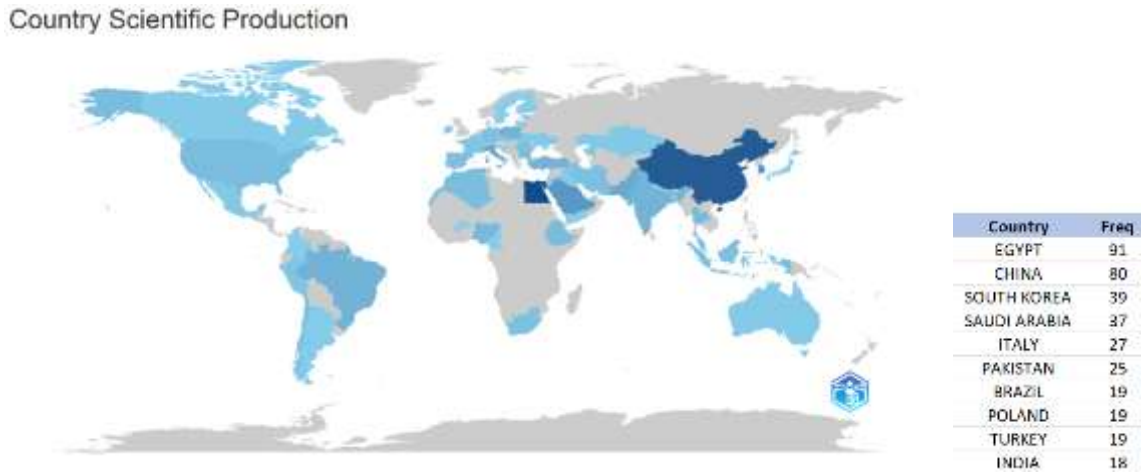


Figure 3. Top Contributing Countries in Scientific Publications on Chlorogenic Acid, Antidiabetic Activity, and Reproductive Hormones (2015–2025)

Source Dynamics on Chlorogenic-Related Research (2015-2025)

Figure 4 illustrates that researchers have published studies on chlorogenic acid, antidiabetic activity, and reproductive hormones in several high-impact journals over the past decade. The analysis highlights Molecules and Nutrients as the most productive, each publishing 10 articles from 2015 to 2025. Molecules focuses on the chemical and biological properties of bioactive compounds, while Nutrients emphasizes dietary influences and metabolic regulation. Both journals have consistently increased their output since 2019, reflecting a focus on bioactive compounds, metabolic regulation, and nutraceutical research. Building on this trend, Frontiers in Pharmacology follows, with 7 publications and a significant increase starting in 2020. This aligns with its emphasis on pharmacological mechanisms and molecular targets related to diabetes and reproductive disorders. Scientific Reports ranks fourth with 6 articles, providing multidisciplinary research on oxidative stress, hormone regulation, and phytochemical activity. Other key sources include Foods (5 articles), Antioxidants (4 articles), and Evidence-Based Complementary and Alternative Medicine (4 articles). Foods addresses functional foods, Antioxidants explores antioxidant mechanisms, and Evidence-Based Complementary and Alternative Medicine investigates natural therapeutic agents.

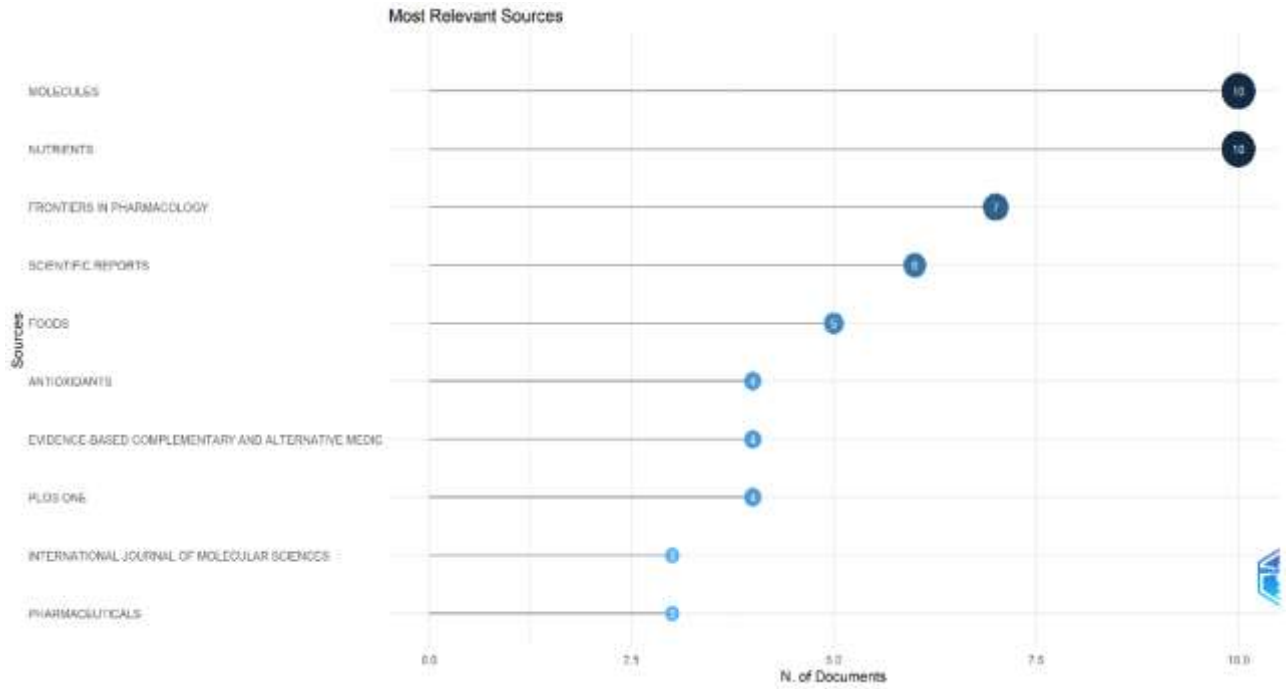


Figure 4. Most Relevant Sources in Chlorogenic Acid Research

As more studies on plant-based metabolism have been conducted since 2019, *Figure 5* demonstrates that molecules and nutrients have taken center stage. This increased focus appears to coincide with the rapid expansion of publications in Frontiers in Pharmacology and Scientific Reports after 2021, likely due to interdisciplinary research into how chlorogenic acid affects reproductive and glucose metabolism.

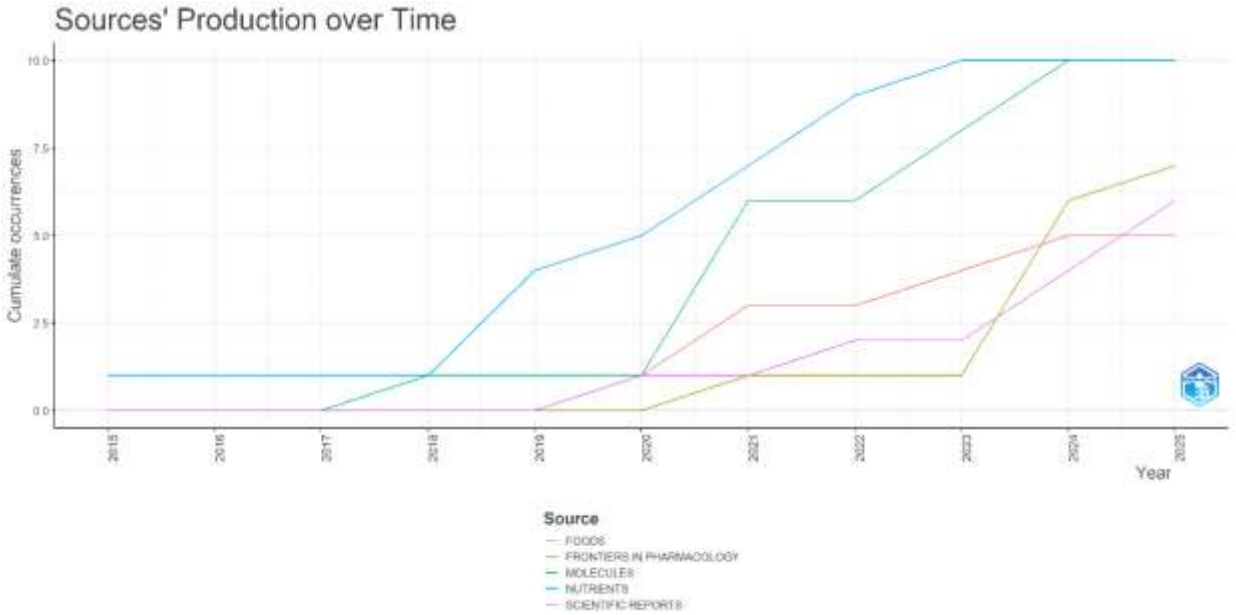


Figure 5. Source Dynamics of Chlorogenic Acid Publications

Keyword Co-occurrence

The network visualization depicts the co-occurrence of keywords in chlorogenic acid research. Node size represents frequency of appearance, while connecting lines indicate the strength of thematic relationships among terms. Three distinct clusters are identified. First, the red cluster is characterized by phytochemical and antioxidant terms such as chlorogenic acid, plant extract, flavonoid, and quercetin, reflecting a focus on bioactive compounds and their chemical characterization. Transitioning to the green cluster, this group centers on experimental and physiological research, with keywords including oxidative stress, animal experiment, insulin, metformin, and superoxide dismutase, indicating investigations into antidiabetic mechanisms and metabolic regulation in animal models. Moving to the blue cluster, this cluster is associated with molecular and metabolic pathways, including signal transduction, metabolism, and insulin resistance, highlighting mechanistic and cellular-level studies. The central positioning of terms such as article, controlled study, and nonhuman indicates that research in this field is primarily preclinical and experiment-based. This clustering pattern is consistent with previous bibliometric findings and suggests an integrated approach that connects phytochemistry, oxidative stress modulation, and metabolic control mechanisms in the study of the antidiabetic and reproductive potential of chlorogenic acid. (*Figure 6*)

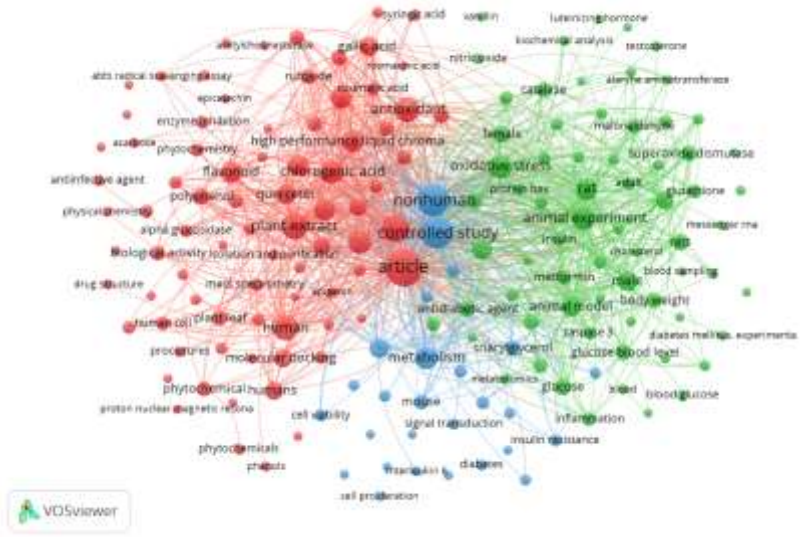


Figure 6. Keyword Co-occurrence Network of Chlorogenic Acid Research

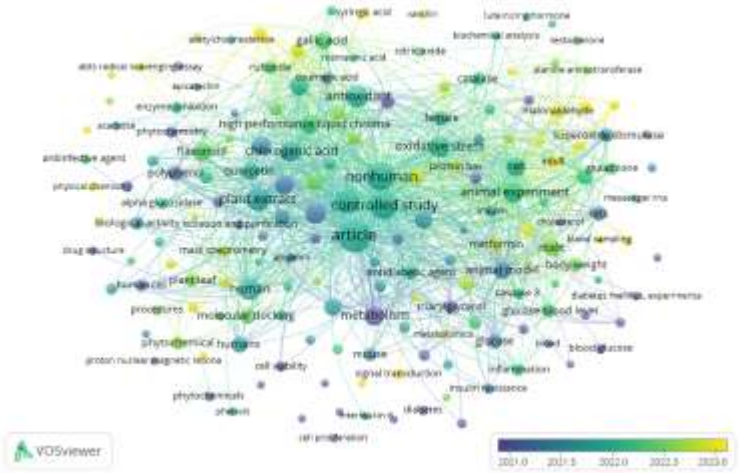


Figure 7. Overlay Visualization of Keyword Co-occurrence in Chlorogenic Acid Research

The overlay visualization (*Figure 7*) depicts the evolution of chlorogenic acid research themes from 2021 to 2023. The color gradient represents the average publication year for each keyword. Blue to purple tones indicate earlier studies that primarily address phytochemical characterization and antioxidant evaluation, as evidenced by the prominence of terms such as phenols, flavonoids, gallic acid, enzyme inhibition, and mass spectrometry. These terms reflect foundational research focused on compound isolation and chemical profiling of plant-derived bioactives. In contrast, green to yellow tones represent more recent research trends emerging after 2022, characterized by keywords such as oxidative stress, animal experiment, insulin resistance, and metformin. This shift suggests an increasing integration of chlorogenic acid into metabolic and endocrinological research. The presence of keywords such as superoxide dismutase, malondialdehyde, and testosterone in yellow further highlights a current emphasis on oxidative and hormonal regulation mechanisms associated with diabetes and reproductive health outcomes.

The progressive color transition indicates a distinct temporal and thematic shift from phytochemical and analytical studies to biological, mechanistic, and translational research over the past three years. This trend is consistent with recent Scopus-indexed publications. Wang, et al. (2022) described the antidiabetic and antioxidant mechanisms of chlorogenic acid in diabetic models (19). Similarly, Zheng, et al. (2023) highlighted its potential to modulate oxidative stress and enhance insulin sensitivity (20). Collectively, this bibliometric evidence demonstrates the thematic evolution of chlorogenic acid research from compound discovery to physiological application, emphasizing its emerging significance in metabolic and reproductive regulation.

Author and Country Network

The collaboration network map (*Figure 8*) illustrates the co-authorship structure among researchers in the field, revealing seven distinct clusters that represent different collaborative groups. The largest and most cohesive cluster, led by Abou Fayssal Sami, Bachheti Archana Joshi, and Belayneh Asfaw Tilahun, indicates strong intra-group collaboration and thematic consistency. This cluster's density suggests that these authors frequently co-publish, likely reflecting a shared research focus or institutional affiliation. Meanwhile, another prominent cluster formed by Bugianesi Elisabetta and Dicker Dror R exhibits high centrality and PageRank values, signifying influential contributors who connect multiple research streams. Such central authors act as bridges in the bibliometric network, facilitating knowledge exchange across subdomains. Smaller and more isolated clusters, such as those led by Hussain Liaqat, Asif Muhammad Talha, and Schreiner Tamara, demonstrate localized collaborations with limited cross-group interaction. This fragmentation implies a moderate level of research integration within the field, where authors tend to collaborate within institutional or regional boundaries rather than forming global partnerships. The overall network structure indicates that while certain nodes exhibit strong co-authorship ties, inter-cluster connectivity remains relatively sparse. This pattern aligns with the notion that scientific collaboration often develops within thematic or geographical niches before expanding into transnational networks, as discussed in previous bibliometric analyses. Strengthening inter-cluster collaborations could enhance innovation and foster interdisciplinary integration in future research.

Figure 8. Author Collaboration Network Map in Chlorogenic Acid Research

The country collaboration map (*Figure 9*) illustrates the global distribution and intensity of international research partnerships. Collaborations concentrate in Asia, Europe, and the Middle East, but are limited in most African nations and parts of South America. China, as the most active contributor, displays dark color intensity and a central network position, especially through collaborations with Europe and neighboring Asia. Saudi Arabia, India, and Italy act as regional hubs with bilateral partnerships that connect continents. The United States, Australia, the United Kingdom, and Brazil demonstrate moderate engagement, bridging research communities in developed and developing regions. These variations highlight uneven collaborative activity and underline a need for more inclusive scientific exchange in underrepresented areas. The overall pattern shows a North–South structure, with high-income countries dominating output and connectivity, while emerging nations join through targeted partnerships. These findings align with previous bibliometric studies emphasizing the importance of international collaboration for research visibility and citation impact.

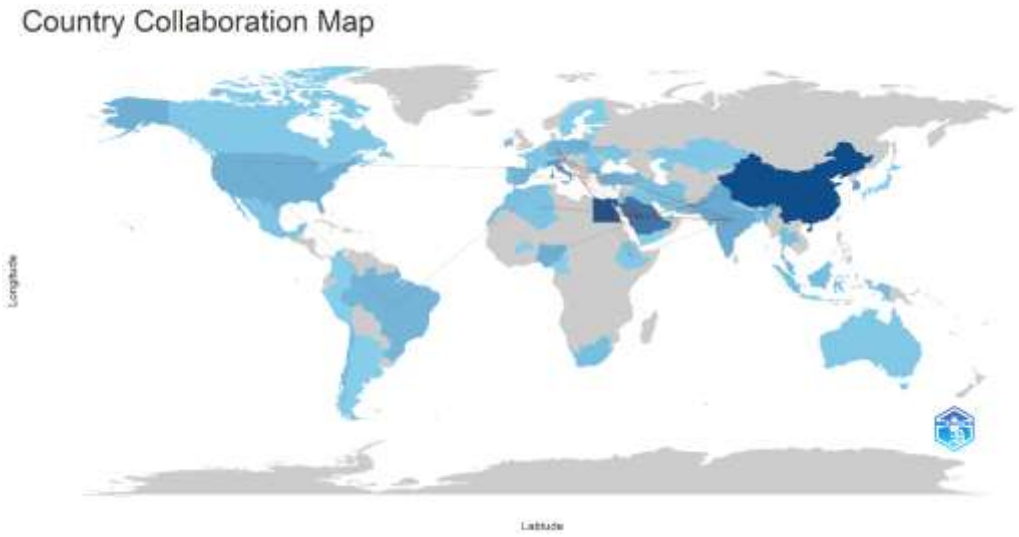


Figure 9. Countries' Collaboration World Map in Chlorogenic Acid Research

Research Gaps And Potential Topics

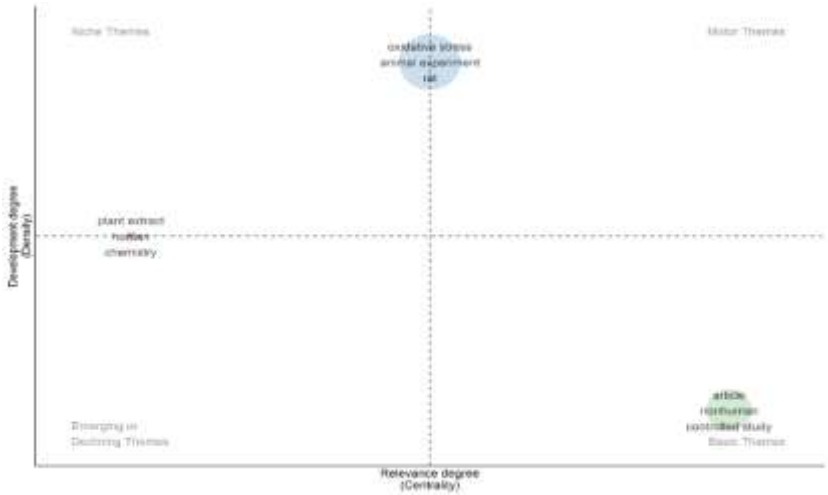


Figure 10.Thematic Map of Research Gaps and Potential Topics in Chlorogenic Acid Research

The thematic map (*Figure 10)* classifies research themes by development degree (density) and relevance degree (centrality), reflecting the intellectual maturity and connectivity of the field. Four quadrants were identified. The niche themes quadrant (upper left) includes terms such as oxidative stress, animal experiment, and rat, which represent highly developed yet isolated topics. These topics indicate an intense focus on experimental and mechanistic studies that utilize preclinical models to evaluate the antioxidant and metabolic effects of chlorogenic acid. Such studies have elucidated biochemical pathways of oxidative damage and insulin regulation. However, the limited connections to human-centered research reveal a translational gap that warrants further exploration. In contrast, the basic themes quadrant (lower right), represented by article, nonhuman, and controlled study, reflects foundational but less conceptually advanced elements. This pattern suggests that methodological rigor is maintained, yet the field remains theoretically underdeveloped. The emerging or declining themes quadrant (lower left), including plant extract, human, and chemistry, encompasses transitional areas that bridge phytochemistry and biomedicine. These areas may be reinvigorated by integrating modern omics technologies and computational modeling. The absence of themes in the motor quadrant (upper right) demonstrates a lack of dominant, clinically relevant topics that connect preclinical and translational findings. This highlights the need for interdisciplinary work that combines oxidative stress modulation, metabolic control, and reproductive health outcomes. Bridging animal-based oxidative stress investigations with human clinical studies, using systems pharmacology, metabolomics, and network-based modeling, is recommended. This approach may reveal new therapeutic insights into the roles of chlorogenic acid in diabetes-associated infertility, sexual dysfunction, and metabolic restoration, thereby advancing the field from isolated experimental evidence to integrative biomedical applications.

DISCUSSION

The results show a strong and steady increase in worldwide research on chlorogenic acid (CGA) from 2015 to 2025, especially about diabetes and hormone regulation. This steady growth shows a shift in medical research, with substances like CGA being studied not just as antioxidants but also as chemicals that help balance the body's systems. The number of studies increased sharply between 2020 and 2024, matching a global rise in research on health-boosting foods and plant-based medicine. Diabetes and infertility, once seen as separate issues, are now recognized as connected by problems like insulin resistance and cell stress (15). The growing interest in CGA can be seen as part of a move from single-target treatments to using natural compounds to support both metabolism and hormones (11).

Geographically, Egypt, China, South Korea, and Saudi Arabia lead research in Asia and the Middle East, showing these regions are important for new plant-based and medical research. Egypt stands out for studying men's reproductive health and plant-based diabetes treatments. China's research is driven by strong government programs focused on learning about natural products and molecular medicine. South Korea and Saudi Arabia are also growing centers for plant-based medicine, using both traditional herbal knowledge and modern lab techniques. Western Europe and Latin America are less involved, which creates an ongoing gap in research collaboration and may limit how widely results apply. Working together across continents is important to cover different populations and make sure CGA research can be repeated. Partnerships between leading Asian countries and high-tech Western labs could help us better understand the compound's availability in the body, how it works, and how it could be used.

The keyword co-occurrence analysis shows how CGA research topics have changed over time. Three main groups appeared: the red group is about chemical details and antioxidant activity (keywords: chlorogenic acid, phenols, flavonoids, quercetin); the green group focuses on animal studies and metabolism (keywords: oxidative stress, insulin resistance, metformin, glucose metabolism); and the blue group looks at molecular and hormone-related processes (keywords: hormone regulation, signal pathways, AMPK, PPARγ, Nrf2). The time-based chart shows a shift from chemistry studies before 2020 to studies exploring biology and mechanisms after 2021. This shows the field has matured from finding compounds to understanding how they work. Now, CGA is being studied for its effects on cell signaling, not just as an antioxidant. These groupings show that CGA research now combines chemistry, hormone science, and drug studies. CGA helps with diabetes by acting on several connected body systems (21). One main way is through a pathway called AMPK, which helps control metabolism. CGA activates AMPK in the liver and muscles, improving sugar use, fat burning, and energy production, and it also slows down sugar creation in the liver (22,23). At the same time, CGA affects another protein, PPARγ, which is important for how the body uses

insulin and handles fat (24). CGA turns on PPARγ, increasing helpful proteins for sugar use and lowering fat in the blood (25,26). CGA also increases the activity of Nrf2, which boosts the production of natural antioxidants that protect the body from damage and support insulin production (5).

Besides affecting blood sugar, CGA helps balance hormones for reproduction (1,5). High blood sugar and poor insulin use can disrupt hormones, leading to problems with fertility. CGA seems to help by improving insulin signals in the brain, lowering harmful inflammation, and protecting reproductive organs from damage. Studies in animals show that CGA normalizes important hormones, helps the ovaries, and increases estrogen. In male diabetic rats, CGA raises testosterone by helping certain proteins and reducing cell damage in the testicles. In these ways, CGA lowers stress in cells caused by high blood sugar and helps correct hormone issues, making it a possible option for treating diabetes related infertility (2,27,28). Furthermore, CGA's effect on gut bacteria shows a new link between metabolism and reproduction. Gut imbalance and toxins in diabetes change Short Chain Fatty Acids (SCFAs), which influence insulin and hormones. CGA helps balance gut bacteria by raising helpful groups like *Bifidobacterium* and *Lactobacillus*, while reducing harmful types such as *Clostridium* and *Desulfovibrio* (29). This balance lowers body wide inflammation and improves metabolic health, which can help hormone production (30). The gut brain gonadal axis then provides another path for CGA to support body regulation, connecting gut health, insulin action, and hormone production (31). This broad effect makes CGA important not just as an antioxidant but as a key factor for metabolic and reproductive health (1).

Collaboration studies show that international partnerships around CGA research are growing but still have limits. Seven main research groups, led by specific researchers, have strong teamwork in their regions but not as much between different regions, limiting global impact. This pattern matches what is seen in research topics, where focus is on metabolism and cell stress, but not enough on hormone studies. Bridging these gaps means more teamwork between drug researchers, hormone experts, chemists, and data analysts. Combining computer simulations, metabolism studies, and broad analysis is key to understanding how CGA interacts with the body and with other natural compounds. Despite progress, this study finds key research gaps. Most studies focus on animal models and oxidative pathways, while main clinical topics are less studied. There are few human or practical studies, and not many assess CGA's long-term safety or effects in people. Also, this analysis used only Scopus and English articles, so it might miss studies from other languages or places. For a fuller view, future research should use more databases and new analysis methods like meta-analysis or machine learning. New ways to deliver CGA could help its safety and use in the body.

Interpretation of Key Findings

The bibliometric analysis demonstrated a consistent increase in global research output related to chlorogenic acid (CGA) from 2015 to 2025, reflecting rising recognition of its dual role in metabolic regulation and reproductive endocrinology. Early research focused on the antioxidant and phytochemical properties of CGA, while recent studies increasingly emphasize its molecular effects on glucose metabolism, insulin signaling, and sex hormone regulation. Notably, the 2020–2024 period saw the most rapid growth, coinciding with global interest in phytotherapeutics targeting diabetes and infertility conditions recognized as metabolically and hormonally linked. Keyword co-occurrence analysis revealed three principal thematic domains: phytochemical and antioxidant properties, metabolic and endocrine mechanisms, and cellular regulation. This thematic progression marks an evolution from compound characterization to functional application. Egypt, China, South Korea, and Saudi Arabia are leading research contributors, underscoring the dominance of Asia and the Middle East in nutraceutical innovation. Limited collaboration in Western and Latin American regions signals a need for global partnerships. Leading sources such as Molecules and Nutrients illustrate the field's interdisciplinary nature, integrating chemical, nutritional, and biomedical aspects. These findings converge thematically and methodologically, as research increasingly frames CGA as a multifunctional compound that modulates oxidative stress, improves insulin sensitivity via AMPK and PPARγ pathways, and restores hormonal balance in diabetes (1,4,23,32). However, the scarcity of human clinical studies and limited translational frameworks highlights ongoing research gaps. Moving forward, expanding collaborative efforts and prioritizing rigorous clinical trials will be essential to fully translate CGA's multifaceted benefits into effective therapeutic strategies for metabolic and reproductive disorders.

Comparison with Previous Studies

This study demonstrates that chlorogenic acid (CGA) has dual regulatory effects on metabolic function and reproductive hormone balance, aligning with prior evidence. CGA is recognized for enhancing insulin sensitivity, modulating glucose metabolism, and reducing oxidative stress mechanisms reflected in bibliometric clusters within this research, particularly those related to oxidative stress, insulin resistance, and AMPK signaling (33). Yan et al. (2022) reported that CGA significantly improved glucose tolerance and lipid metabolism in high-fat diet mice via AMPK activation and inflammation suppression, confirming its metabolic effect (34). Similarly, Wang et al. (2021) showed that CGA ameliorates endothelial dysfunction in diabetic models via the Nrf2 pathway, reinforcing its antioxidant and anti-inflammatory properties (35). Recent studies also highlight CGA's influence on reproductive endocrinology. Zhang et al. (2023) confirmed its impact on steroidogenic enzymes and follicular development. In male diabetic models (20), Al-Megrin, et al. (2020) found CGA-rich coffee extract reduced testicular oxidative damage and increased testosterone, supporting its potential to ameliorate diabetes related hypogonadism (27). Collectively, these findings indicate CGA functions as a pleiotropic compound linking glucose homeostasis, oxidative stress defense, and reproductive hormone regulation (36). Bibliometric evidence from this study extends these findings, showing global CGA research is moving toward interdisciplinary approaches connecting metabolic regulation and endocrine health.

Limitations and Cautions

Several important limitations should be considered when interpreting this study's findings. First, the analysis included only English-language publications indexed in Scopus, potentially excluding relevant studies from other languages and regional journals, especially from countries with emerging research in phytochemistry and natural product pharmacology. Such restrictions may introduce selection bias and not fully capture the global diversity of CGA-related research. Second, as with most bibliometric analyses, this study focuses on mapping research trends and thematic structures rather than assessing the methodological quality or experimental validity of individual studies. While dominant themes such as antidiabetic mechanisms, oxidative stress, and reproductive hormone regulation are identified, the clinical effectiveness of the findings is not evaluated. Third, because data were extracted from Scopus alone, studies indexed in other major databases such as Web of Science or PubMed may have been missed, possibly limiting the scope of network visualizations and citation mapping. Finally, bibliometric indicators such as citation counts and keyword co-occurrence represent quantitative rather than qualitative significance, as high citation frequency may reflect publication visibility rather than scientific rigor, and keyword clustering may be influenced by indexing conventions. Given these considerations, the results of this study should be viewed as exploratory and descriptive, offering an overview of global research dynamics rather than definitive conclusions about the biochemical efficacy or therapeutic potential of CGA. Future studies should integrate data from multiple databases and combine bibliometric mapping with systematic or meta-analytic approaches for greater comprehensiveness.

Recommendations for Future Research

Future research on chlorogenic acid (CGA) should focus on the following key areas: 1) Lucidating mechanisms of action through in vitro, in vivo, and clinical trials, specifically investigating insulin sensitivity, oxidative stress pathways, and hormonal regulation via AMPK, PPARγ, and Nrf2. 2) Applying multi-omics approaches genomics, transcriptomics, proteomics, and metabolomics to identify affected gene and protein targets, and to elucidate systemic effects on metabolic and endocrine networks. 3) Improving CGA bioavailability and pharmacokinetics by developing advanced delivery systems such as nanoemulsions, liposomes, or polymeric nanoparticles.4) Conducting translational and population-based studies in diverse demographic groups to rigorously evaluate CGA's safety, dosage, and long-term reproductive outcomes. 5) Fostering interdisciplinary collaboration among pharmacologists, endocrinologists, nutritionists, and computational scientists to integrate biochemical, clinical, and data-driven perspectives. 6) Performing bibliometric analyses using multiple databases (Scopus, Web of Science, PubMed, Embase) and advanced analytical tools, including machine learning, to map the research landscape and forecast trends. 7) Direct comparative clinical trials of CGA versus standard pharmacotherapies to assess synergistic or complementary effects.

CONCLUSION

This bibliometric study shows a significant global increase in chlorogenic acid (CGA) research from 2015 to 2025, underscoring its expanding scientific importance as a bioactive compound with antidiabetic and hormone-regulating properties. Most publications are from Egypt, China, South Korea, and Saudi Arabia, indicating greater research capacity and leadership in phytochemical and metabolic endocrine studies. Thematic analysis highlights four main domains: metabolic regulation, oxidative stress, hormonal modulation, and molecular signaling. There is a shift from antioxidant research to more mechanistic and translational studies. CGA research now connects metabolism, reproductive endocrinology, and molecular pharmacology. Notable gaps remain, especially in clinical validation, bioavailability, and long-term safety in humans. Addressing these gaps requires multi-omics approaches, new drug delivery systems, and international collaboration.

AUTHOR'S CONTRIBUTION STATEMENT

Eko Naning Sofyanita was the principal author in charge of creating the conceptual framework, searching the literature, evaluating bibliometric information, and composing the first draft of the paper. Achmad Zulfa Juniarto undertook critical revisions of the article's scientific content, offered academic supervision, and helped build the technique. Ari Suwondo helped with the creation of the discussion and policy implications parts, as well as the validation of the analysis results and interpretation of findings in the context of public health. Heri Nugroho carried out a final assessment of the manuscript's scholarly and language quality and offered conceptual help, especially in the integration of clinical medicine components. All of the authors have reviewed and approved the final draft of this paper, and they all pledge to take responsibility for every part of it to maintain its correctness and scientific integrity.

CONFLICTS OF INTEREST

The authors state that no academic, financial, commercial, or personal conflicts of interest could affect the article's writing, interpretation, or findings. Without any input from other parties interested in the subject matter, the whole research and writing process was carried out alone.

DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

In the process of creating this paper, no scientific information was explicitly created, analyzed, or compiled using generative artificial intelligence technology (like ChatGPT or other tools). Based on manual analysis and a survey of the literature, the authors came up with all of the concepts, interpretations, and writing. To help with data processing and the development of scientific network maps, several non-generative AI-based tools were utilized, nevertheless, such as reference management software and bibliometric visualization tools (such VOSviewer and Biblioshiny). The study team independently verified and analyzed each analysis outcome.

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