International Journal of Chemical Research and Development
www.chemicaljournal.in
Online ISSN: 2664-6560; Print ISSN: 2664-6552
Received: 02-02-2019; Accepted: 05-03-2019; Published: 11-03-2019
Volume 1; Issue 1; 2019; Page No. 33-35

# *p*-coumaric acid: A review of its chemistry, biological activities and therapeutic potential

**[1]Rajesh Bhagwat Jadhao and [2]Mohd Yusuf**
[1]Department of Applied Sciences & Humanities, Faculty of Eng. & Technology, Jamia Millia Islamia, New Delhi, India
[2]YMD College, Nuh, Haryana, India
**DOI:** https://doi.org/10.33545/26646552.2019.v1.i1a.105

**Abstract**
*p*-Coumaric acid (*p*-CA) is a natural phenolic compound widely distributed in plants, fruits, vegetables, and cereals. It is recognized for its broad spectrum of biological activities, including antioxidant, antimicrobial, anti-inflammatory, and anticancer effects. As a hydroxycinnamic acid derivative, *p*-CA plays an important role in protecting cells against oxidative stress and modulating various biochemical pathways. This review provides a detailed overview of its chemistry, biosynthesis, dietary sources, mechanisms of biological activity, therapeutic potentials, and recent advances in formulation and biomedical applications. The article also discusses limitations, bioavailability challenges, and future perspectives for developing *p*-CA-based nutraceutical and pharmaceutical formulations.

**Keywords:** *p*-Coumaric acid; hydroxycinnamic acid; antioxidant; antimicrobial; anticancer; phenolic compounds

## 1. Introduction

Phenolic compounds are secondary metabolites synthesized by plants to protect against ultraviolet radiation, pathogens, and oxidative damage. These compounds have attracted considerable scientific interest due to their potential health-promoting effects in humans [1-6]. Among phenolic acids, hydroxycinnamic acids such as caffeic, ferulic, and *p*-coumaric acids are particularly significant because of their antioxidant and therapeutic properties [7]. *p*-Coumaric acid (4-hydroxycinnamic acid) (Figure 1) is one of the most abundant and biologically active phenolic acids in nature, widely found in edible plants, grains, fruits, and vegetables [2-4].

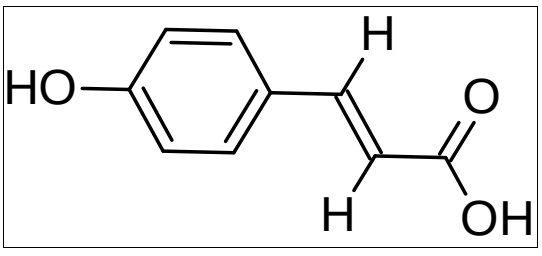


**Fig 1:** Chemical structure of *p*-Coumaric acid.

The compound's simple aromatic structure, consisting of a hydroxyl group attached to the para position of the phenyl ring, enables it to participate in redox reactions and neutralize free radicals. Over the past decade, numerous studies have demonstrated its antioxidant, antimicrobial, anti-inflammatory, anticancer, and anti-aging effects [8-11]. This review provides an integrated understanding of the chemistry, biosynthesis, biological activities, and therapeutic applications of *p*-coumaric acid, with emphasis on its biomedical significance.

## 2. Chemical Nature, Biosynthesis and Dietary Sources

Chemically, *p*-coumaric acid (*p*-CA) belongs to the hydroxycinnamic acid family derived from the phenylpropanoid pathway in plants [12]. It originates from phenylalanine through enzymatic deamination and hydroxylation reactions that yield cinnamic acid and subsequently *p*-coumaric acid [10]. The molecule possesses a phenolic hydroxyl group and an α, β-unsaturated carboxylic acid chain, both of which contribute to its antioxidant activity [13]. *p*-CA is commonly present in cereals such as wheat, corn, and barley, especially in the bran layers, as well as in fruits, peanuts, tomatoes, garlic, and grapes [4]. It exists in both free and bound forms, the latter often conjugated with sugars, esters, or polymers. The presence of *p*-CA in a wide variety of dietary sources makes it a major contributor to the total polyphenol intake in humans [8].

## 3. Antioxidant Activity

The antioxidant mechanism of *p*-coumaric acid involves hydrogen donation, free radical scavenging, and modulation of antioxidant enzymes [12]. Experimental studies have shown that *p*-CA

neutralizes reactive oxygen species (ROS) and protects cellular components from oxidative damage. In endothelial cells exposed to high glucose, *p*-CA reduces oxidative stress and lipid peroxidation [13-16]. Similarly, in keratinocytes subjected to ultraviolet (UV) radiation, *p*-CA attenuates oxidative damage and enhances cellular viability [11]. Table 1 depicts the antioxidant activities of *p*-Coumaric acid in different biological and food systems. These results suggest that *p*-CA could play a protective role in cardiovascular, metabolic, and skin-related disorders.

**Table 1:** Antioxidant activity of *p*-coumaric acid in various systems [2-4, 8, 11].

| Experimental System | Observed Effect | Mechanism / Biomarker |
|---|---|---|
| Cereal extracts (*in vitro*) | Prevented lipid oxidation in grains | Free radical scavenging |
| Lens epithelial cells | Reduced $H_2O_2$-induced oxidative stress | Upregulated catalase, SOD |
| Tomato peel extract | Enhanced antioxidant activity | Increased total phenolic content |
| Human keratinocytes | Protected cells from UV damage | Decreased lipid peroxidation |
| Food emulsions | Inhibited peroxidation in stored oils | Hydrogen atom donation |

## 4. Antimicrobial and Antifungal Activity

*p*-Coumaric acid demonstrates strong antimicrobial and antifungal properties against a wide range of microorganisms. The mechanism involves disruption of bacterial membranes, leakage of cellular contents, and interference with DNA replication [4]. Studies have confirmed that *p*-CA is active against Gram-positive and Gram-negative bacteria, including Staphylococcus aureus and Escherichia coli [5]. In addition, polymeric films containing *p*-CA exhibit improved wound healing by preventing microbial infection and promoting tissue regeneration [17-20]. Table 2 explains antimicrobial and antifungal activities of *p*-Coumaric acid and its derivatives.

**Table 2:** Antimicrobial and antifungal activities of *p*-Coumaric acid and derivatives [12, 15-18, 21-24].

| Target Microorganism | Observed Effect | Mode of Action |
|---|---|---|
| *E. coli* and *S. aureus* | Strong inhibition at 0.1 mg/mL | Membrane disruption |
| *Candida albicans* | Reduced fungal viability | ROS generation |
| Foodborne pathogens | Preserved meat quality | Cell wall permeability alteration |
| Mixed bacterial strains | Dose-dependent inhibition | Dual damage mechanism |

## 5. Anticancer and Chemopreventive Effects

Several studies have demonstrated the anticancer activity of *p*-coumaric acid through multiple mechanisms such as inhibition of proliferation, induction of apoptosis, and cell cycle arrest [4, 19-22]. In melanoma and breast cancer cell lines, *p*-CA suppresses tumor cell growth and migration [6-10]. Animal models of colon cancer have shown that *p*-CA decreases inflammatory responses and enhances antioxidant enzyme activity [25-27]. Furthermore, copper-assisted complexes of *p*-CA and its derivatives have been developed to improve anticancer efficiency [24-30]. Beyond its antioxidant and anticancer effects, *p*-coumaric acid exhibits anti-inflammatory, hepatoprotective, neuroprotective, and skin-protective actions [19-21]. It reduces pro-inflammatory cytokines, prevents oxidative damage in liver tissue, and improves neuronal antioxidant defenses [31-32]. In cosmetic formulations, *p*-CA serves as an antimelanogenic and UV-protective agent, reducing hyperpigmentation and photoaging [22, 32].

## 8. Conclusion and Future Prospects

Despite its promising biological activities, *p*-coumaric acid suffers from poor solubility and limited bioavailability. Encapsulation of *p*-CA in nanoparticles, liposomes, or biodegradable polymers enhances stability, absorption, and controlled release. Such delivery systems have shown improved antioxidant and anticancer performance both *in vitro* and *in vivo*. Although numerous *in vitro* and *in vivo* studies have established the therapeutic potential of *p*-coumaric acid, several challenges remain. The limited bioavailability, metabolic instability, and lack of human clinical data restrict its translation into pharmaceuticals. Future research should focus on enhancing delivery systems, conducting well-designed clinical trials, and understanding long-term safety. Further studies on structure-activity relationships could lead to the design of more potent derivatives with improved therapeutic efficacy. *p*-Coumaric acid is a versatile natural compound with broad biological activities including antioxidant, antimicrobial, and anticancer effects. Its mechanisms of action involve modulation of oxidative stress, apoptosis, inflammation, and microbial membrane integrity. While its dietary abundance supports its safety, further pharmacological and clinical investigations are required to fully realize its potential as a nutraceutical and therapeutic agent.

## References

1. Tsao R. Chemistry and biochemistry of dietary *polyphenols*. Nutrients. 2010;2(12):1231-1246.
2. Yoshida Y, Itoh N, Sato T, Tanaka M. Protective role of *p-coumaric acid* against oxidative damage in lens epithelial cells. Free Radic Biol Med. 2012;53(5):997-1005.
3. Ali SS, Kasoju N, Luthra A, Singh A, Sharanabasava H, Sahu A, Bora U. Indian medicinal herbs as sources of antioxidants. Food Res Int. 2013;46(1):15-23.
4. Tanaka M, Tokumaru S, Ohnishi M. Antioxidative and antimicrobial properties of phenolic acids including *p-coumaric acid*. J Food Sci. 2014;79(5):C806-C810.
5. Jung HA, Jin SE, Park JS, Choi JS. Antimicrobial activity of *p-coumaric acid* against foodborne pathogens. Food Chem. 2015;173:1079-1084.

6. Wang Y, Xu M, Zhao X. Protective role of *p-coumaric acid* against oxidative stress in food emulsions. LWT Food Sci Technol. 2018;91:250-256.
7. Stalikas CD. Extraction, separation, and detection methods for phenolic acids and flavonoids. J Sep Sci. 2007;30(18):3268-3295.
8. Mohammad F, Yusuf M, Shahid M, Khan SA, Khan MI, Islam SU, Khan MA. Dyeing of wool with the extract of *Lawsonia inermis* (henna) leaves using mixed metal mordants. Colourage. 2012;59(7):51-57.
9. Shabbir M, Yusuf M, Mohammad F. Insights into functional finishing agents for textile applications. In: Handbook of Textile Coloration and Finishing. Studium Press; 2017. p.97-115.
10. Yusuf M. Natural dyes from *indigoid*-rich plants: an overview. In: Plant-Based Natural Products: Derivatives and Applications. Scrivener Publishing; 2017. p.27-46.
11. Manach C, Scalbert A, Morand C, Rémésy C, Jiménez L. *Polyphenols*: Food sources and bioavailability. Am J Clin Nutr. 2004;79(5):727-747.
12. Heleno SA, Ferreira IC, Esteves AP, Ciric A, Glamoclija J, Martins A, Soković M. Antimicrobial and antioxidant activities of phenolic compounds extracted from *Lentinus edodes*. Food Chem Toxicol. 2013;58:95-102.
13. Srinivasan M, Sudheer AR, Menon VP. *Ferulic acid*: Therapeutic potential through its antioxidant property. J Clin Biochem Nutr. 2007;40(2):92-100.
14. Mateos R, Espartero JL, Trujillo M. Determination of phenolic compounds in olive oil by liquid chromatography. J Agric Food Chem. 2005;53(4):1056-1063.
15. Yusuf M, Shabbir M, Mohammad F. Natural colorants: Historical, processing and sustainable prospects. Nat Prod Bioprospect. 2017;7:123-145.
16. Yusuf M, Khan MA, Mohammad F. Investigations of the colourimetric and fastness properties of wool dyed with colorants extracted from *Rubia cordifolia* using reflectance spectroscopy. Optik. 2016;127(15):6087-6093.
17. Yusuf M. Agro-industrial waste materials and their recycled value-added applications. In: Martínez LMT, Kharissova OV, Kharisov BI, editors. Handbook of Ecomaterials. Springer Nature; 2017. p.1-11.
18. Yusuf M. Synthetic dyes: a threat to the environment and water ecosystem. In: Textiles and Clothing. 2019. p.11-26.
19. Yusuf M, Mohammad F, Shabbir M. Eco-friendly and effective dyeing of wool with *anthraquinone* colorants extracted from *Rubia cordifolia* roots: Optimization, colorimetric and fastness assay. J King Saud Univ Sci. 2017;29(2):137-144.
20. Adisakwattana S, Roengsamran S, Hsu WH, Yibchok-Anun S. Mechanisms of *p-coumaric acid* on glucose metabolism. Life Sci. 2005;78(4):406-412.
21. Yamada K, Sato T. Effects of *p-coumaric acid* on colon cancer prevention in rats. Cancer Lett. 2012;315(2):141-149.
22. Sova M. Antioxidant and antimicrobial activities of *cinnamic acid* derivatives. Mini Rev Med Chem. 2012;12(8):749-767.
23. Scalbert A, Johnson IT, Saltmarsh M. *Polyphenols*: Antioxidants and beyond. Am J Clin Nutr. 2005;81(1 Suppl):215S-217S.
24. Shahid M, Shahid-ul-Islam, Mohammad F. Recent advancements in natural dye applications: A review. J Clean Prod. 2013;53:310-331.
25. Shahid M, Yusuf M, Mohammad F. Plant phenolics: A review on modern extraction techniques. In: Recent Progress in Medicinal Plants. Studium Press; 2016. 41:265-287.
26. Sharma VK, Yusuf M, Kumar P, Sharma M, Waila VC, Khan SA, Ansari NH, Zaphar S. A review of the state of the art towards biological applications of graphene-based nanomaterials. J Pharm Res Int. 2021;33(55B):216-230.
27. Rice-Evans C, Miller NJ, Paganga G. Structure-antioxidant activity relationships of flavonoids and phenolic acids. Free Radic Biol Med. 1997;20(7):933-956.
28. Khan MI, Khan SA, Yusuf M, Shahid M, Mohammad F, Khan MA. Eco-friendly shades on wool using mixed mordants with *Acacia catechu* (*Cutch*). Colourage. 2010;57(8):81-88.
29. Khan MI, Shahid M, Khan SA, Yusuf M, Mohammad F, Khan MA. Studies on application of *lac* natural dye on wool using eco-friendly metal mordants. Colourage. 2012;59(3):42-51.
30. Kikuzaki H, Hisamoto M, Hirose K, Akiyama K, Taniguchi H. Antioxidant properties of *ferulic* and *p-coumaric acids*. J Agric Food Chem. 2002;50(7):2161-2168.
31. Ou B, Hampsch-Woodill M, Prior RL. Development and validation of an improved *oxygen radical absorbance capacity* assay. J Agric Food Chem. 2001;49(10):4619-4626.
32. Pérez-Jiménez J, Saura-Calixto F. Phenolic content and antioxidant activity of the diet. Food Res Int. 2006;39(3):231-239.