

Quercetin from *Buchanania lanzan* (Chironji): Extraction, Bioactivity and Pharmaceutical Cocrystal Development—A Review

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Abstract

Buchanania lanzan Spreng., popularly known as Chironji, Charoli or Priyal, is a medicinally valuable tree belonging to the family Anacardiaceae. Its edible kernels are nutritionally important and provide proteins, lipids, minerals and several bioactive constituents. Studies on extracts prepared from different parts of the plant have reported antioxidant, antidiabetic, anticholinesterase and anti-inflammatory activities. Phytochemical investigations have revealed the presence of phenolic acids, flavonoids, tannins, terpenoids, sterols and fatty acids. HPLC analysis of hydroalcoholic seed-kernel extracts has also reported compounds such as gallic acid, chlorogenic acid, caffeic acid, rutin and quercetin, indicating the potential importance of its phenolic constituents.

Quercetin is a naturally occurring flavonol known for its antioxidant and anti-inflammatory properties. However, its poor water solubility, strong crystal lattice and limited oral bioavailability restrict its wider pharmaceutical application. Several strategies, including nanoencapsulation, lipid-based formulations, cyclodextrin complexes, solid dispersions and pharmaceutical cocrystals, have been investigated to overcome these limitations. Among these approaches, cocrystallization offers the advantage of modifying the solid-state properties of an active compound without changing its chemical structure.

This review examines the botanical, nutritional and phytochemical importance of *B. lanzan* and summarizes reported biological activities and methods for the extraction and analysis of quercetin. It further discusses a practical experimental approach involving seed defatting, hydroalcoholic extraction, ethyl-acetate fractionation, HPTLC or HPLC standardization and screening for cocrystal formation. Rather than claiming Chironji as a newly discovered source of quercetin, the review explores the possibility of converting a standardized quercetin-rich fraction, or isolated quercetin, into a well-characterized cocrystal with improved solubility, dissolution and stability.

Keywords

Buchanania lanzan, Chironji, quercetin, flavonoids, phenolic compounds, HPLC, HPTLC, pharmaceutical cocrystals, natural conformer, solubility, bioavailability.

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1. Introduction

Medicinal plants remain valuable sources of chemically diverse compounds for foods, nutraceuticals and medicines. Phenolics and flavonoids are especially relevant because their structures support a wide range of biological interactions, including antioxidant and anti-inflammatory effects. Quercetin is among the most extensively studied flavonols. Although its biological activity is promising, its low water solubility and modest oral bioavailability have limited its pharmaceutical use.

Buchanania lanzan Spreng. is an underused multipurpose tree of the Anacardiaceae family. It is known by several common names, including Chironji, Charoli, Chaar and Priyal. The species occurs across tropical and subtropical parts of the Indian subcontinent and is important to many forest-dependent and tribal communities. Its kernels are valued as edible nuts and are used in sweets, confectionery and other foods; other parts of the plant also have a place in traditional medicine.

Earlier work established the nutritional value and antioxidant potential of Chironji seeds. Khatoun and colleagues reported appreciable amounts of protein, fat, fibre and minerals, together with phenolic compounds.. The extracts showed antioxidant, antidiabetic and anticholinesterase activity, and HPLC identified gallic acid, chlorogenic acid, caffeic acid, rutin and quercetin. Therefore, a study of quercetin from Chironji should not claim novelty simply from detecting the compound. A stronger contribution would be to establish a reproducible extraction and enrichment method, quantify quercetin reliably, and test whether Chironji-derived quercetin can form a pharmaceutical cocrystal with improved physicochemical properties.

That work sits at the intersection of natural-products chemistry and crystal engineering. The first part involves extraction, fractionation and chromatographic measurement of quercetin. The second involves selecting a suitable coformer and creating a new crystalline phase through changed intermolecular interactions. Cocrystallization is now widely used to explore improvements in the solubility, dissolution, stability and other solid-state properties of poorly soluble compounds.

This review therefore examines the available literature on *B. lanzan* and quercetin and outlines a scientifically sound route for developing cocrystals from Chironji-derived quercetin.

2. Botanical Profile of *Buchanania lanzan*

2.1 Taxonomic classification

Table 1. Taxonomic position of *Buchanania lanzan* Spreng.

Category	Classification
Kingdom	Plantae
Clade	Angiosperms
Order	Sapindales
Family	Anacardiaceae
Genus	<i>Buchanania</i>
Species	<i>Buchanania lanzan</i> Spreng.
Common names	Chironji, Charoli, Priyal, Chaar

B. lanzan is a useful commercial tree native to the Indian subcontinent. The species is valued for several uses because its seeds are edible, its parts are used medicinally, and its trade supports local communities.

2.2 Morphological characteristics

B. lanzan is commonly described as a medium-sized deciduous tree, usually reaching about 10-15 m. It has a fairly stout trunk and spreading branches. The leaves are simple, leathery and elliptic to

broadly ovate. Small flowers appear in terminal or axillary panicles, while the mature fruits are dark drupes. The edible kernel of commercial interest is protected by a hard shell.

3. Ethnomedicinal and Economic Importance

Chironji has long been used in traditional practice. Pharmacognostic reviews describe preparations from different parts of the plant for wounds, diarrhoea and inflammatory complaints, among other uses. The kernel is also economically important: it is eaten directly and used in confectionery, bakery products, sweets, puddings and dairy foods. Its food value, traditional medicinal use and contribution to forest-based livelihoods make Chironji relevant as a nutritional, nutraceutical and medicinal resource.

4. Nutritional Composition of Chironji Seeds

Chironji seeds are rich in protein, lipids, carbohydrates, fibre and minerals, although reported values vary with the plant accession, location, processing and analytical method. Khatoon et al. reported about 43.24% protein, 38% fat, 18.50% crude fibre and 12.96% carbohydrate in their seed samples, along with notable phosphorus, magnesium, calcium and iron. More recent work across several accessions found protein levels of roughly 36.12-42.09%, crude fat of 36.26-39.95% and carbohydrates of 11.33-12.82%, confirming that composition differs among seed sources.

Table 2. Major nutritional constituents in Chironji seeds

Constituent	Importance
Protein	Nutritional and functional value
Lipids	Energy source; edible seed oil
Carbohydrates	Dietary contribution
Dietary fibre	Nutritional and physiological importance
Calcium	Mineral nutrient
Phosphorus	Mineral and metabolic functions
Magnesium	Enzyme and metabolic functions
Iron	Essential micronutrient
Phenolics	Antioxidant potential
Flavonoids	Bioactive secondary metabolites

The high lipid content is also important during analytical work. When the goal is to recover quercetin and other polar phenolics, removing much of the nonpolar oil first can make later extraction and chromatographic analysis cleaner and easier to interpret.

5. Phytochemical Profile of *Buchanania lanzan*

Phytochemical studies of *B. lanzan* have reported several groups of secondary metabolites, including phenolics, flavonoids, tannins, terpenoids and sterols. Reviews published in 2015, 2021 and 2025/2026 summarize findings from different plant parts. Of particular relevance, a 2024 study of seed kernels used HPLC to identify and quantify gallic acid, chlorogenic acid, caffeic acid, rutin and quercetin.

Table 3. Important phytochemical groups reported in *B. lanzan*

Phytochemical Class	Compounds	Pharmacological Properties
Phenolic acids	Gallic acid, chlorogenic acid, caffeic acid	Antioxidant activity

Flavonoids	Quercetin, rutin and related compounds	Antioxidant and pharmacological potential
Tannins	Various tannin constituents	Antioxidant/astringent properties
Terpenoids	Various terpenoid constituents	Biological activity
Sterols	β -Sitosterol	Nutraceutical/pharmacological relevance
Fatty acids	Oleic, linoleic and related fatty acids	Nutritional and functional role
Other volatile/semi-volatile compounds	Several GC-MS-detected compounds	Potential biological contribution

The reported composition of *B. lanzan* can vary with the plant part, extraction solvent and geographic source. For that reason, a claim such as 'Chironji contains X% quercetin' is incomplete unless it also identifies the material tested and the extraction and analytical methods used.

6. Quercetin: Chemistry and Biological Importance

Quercetin is a flavonol, chemically described as 3,3',4',5,7-pentahydroxyflavone. It has the molecular formula $C_{15}H_{10}O_7$ and a molecular mass of about 302.24 g mol⁻¹. Like other flavonoids, it has a C6-C3-C6 framework made up of A, B and heterocyclic C rings. Its five hydroxyl groups contribute to hydrogen bonding and to its redox behaviour.

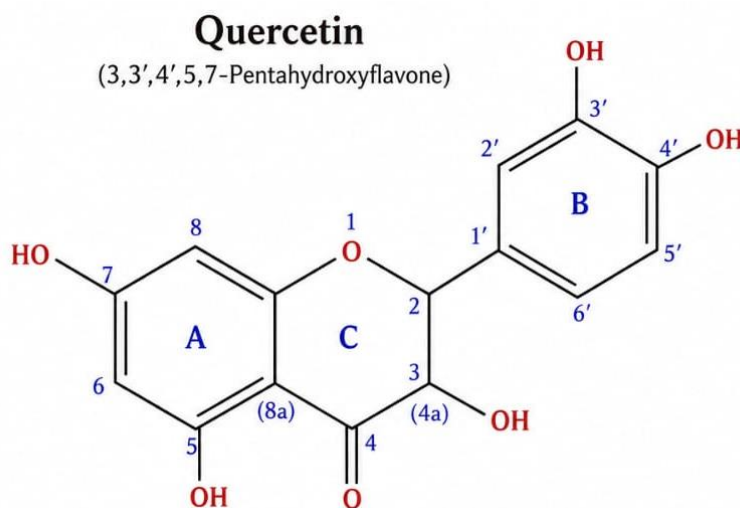


Figure 1.

Quercetin is widely distributed in plants and foods, often in glycosylated form rather than solely as the aglycone. It has been associated with antioxidant, anti-inflammatory, antidiabetic, cardioprotective and antimicrobial effects, among others.

Table 4. Selected biological effects reported for quercetin

Activity	General scientific basis
Antioxidant	Radical scavenging and modulation of oxidative pathways
Anti-inflammatory	Modulation of inflammatory signaling
Antidiabetic	Effects on oxidative stress and metabolic enzymes
Antimicrobial	Reported inhibitory effects against microorganisms

Cardiovascular protection	Effects associated with oxidative and inflammatory pathways
Neuroprotective potential	Modulation of oxidative/inflammatory mechanisms
Anticancer research	Effects on several cellular signalling pathways

Reported biological activity should not be confused with established clinical benefit. Much of the evidence for these effects comes from in-vitro work, animal studies or mechanistic experiments, and clinical translation remains limited in part because of quercetin's pharmacokinetic constraints.

7. Limitations of Quercetin as a Pharmaceutical Candidate

Quercetin's main pharmaceutical drawback is poor aqueous solubility. Exact values depend on temperature, pH, polymorphic form and the method of measurement, but it is consistently regarded as poorly water soluble. Its aromatic structure and strong crystal lattice both contribute to slow dissolution. Other challenges include instability in some environments, extensive metabolism and limited systemic exposure after oral dosing.

Table 5. Major pharmaceutical limitations of quercetin

Limitation	Consequence
Low aqueous solubility	Poor dissolution
Strong crystal lattice	Reduced dissolution rate
Chemical instability under some conditions	Reduced active concentration
Extensive metabolism	Low systemic exposure
Variable absorption	Variable pharmacological response
Low oral bioavailability	Limits pharmaceutical application

These constraints have led to a wide range of formulation approaches, including nanoparticles, liposomes, nanoemulsions, self-emulsifying systems, cyclodextrin complexes, solid dispersions and cocrystals.

8. Extraction of Quercetin and Phenolic Compounds from Chironji Seeds

Extraction strongly affects the amount of quercetin measured, because solvent polarity, time, temperature, sample preparation and the chemical form of the compound all matter. In a recent study of Chironji seed kernels, researchers used solvents of increasing polarity as well as 70% ethanol-30% water for cold maceration at about 25-32 C for 72 h. The hydroalcoholic extract showed antioxidant activity and was analysed by HPLC for phenolic constituents, including quercetin. This provides a useful basis from published work for using hydroalcoholic maceration in an experimental design.

8.1 Defatting

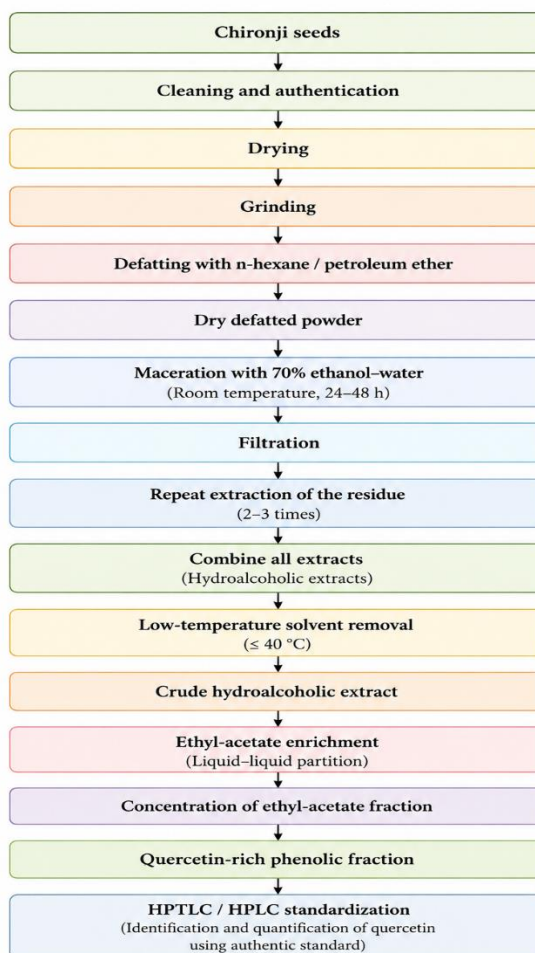
Because Chironji kernels are lipid-rich, a preliminary defatting step can reduce nonpolar material before phenolics are extracted. N-hexane and petroleum ether are commonly suitable choices. Where a Soxhlet apparatus is not available, cold maceration can be used.

For laboratory-scale work, one possible sequence is to clean and shade-dry the seeds, grind them coarsely, and weigh 200 g of powder. Extract the powder in several portions of petroleum ether or n-hexane with intermittent shaking, filter it after an appropriate period, and repeat until the solvent is much less oily or coloured. The remaining residue should be dried thoroughly before hydroalcoholic extraction.

9. Hydroalcoholic Extraction

For a 200 g seed experiment, a reasonable starting point is to extract defatted Chironji powder with 70% ethanol at an initial solid-to-solvent ratio of about 1:10. Maceration for 48-72 h with periodic shaking is practical. The published seed-kernel work supports 70% ethanol-30% water cold maceration for 72 h.

Figure 2.



10. Enrichment of the Quercetin-Rich Fraction

Liquid-liquid partitioning may be used to enrich the quercetin-containing fraction after hydroalcoholic extraction. The concentrated extract may be dispersed in water or aqueous alcohol and partitioned sequentially. An n-hexane fraction removes residual lipid and other highly nonpolar constituents, while ethyl acetate commonly concentrates many medium-polarity phenolics and flavonoids. It should only be called a quercetin-rich fraction after chromatographic analysis has confirmed both the presence and amount of quercetin.

11. HPTLC Identification and Quantification

HPTLC is useful in herbal standardization because the extract and an authentic reference standard can be compared on the same plate. A suitable design would use silica gel 60 F254, quercetin standard, the Chironji extract or fraction, UV detection at 254 and/or 366 nm, and a validated derivatization system such as NP/PEG. The sample should be considered positive only when its

chromatographic behaviour matches the standard under validated conditions. Quantitative HPTLC also requires a calibration curve prepared from several standard concentrations.

13. HPLC Quantification of Quercetin

HPLC is preferable when accurate quercetin quantification is needed. The recent Chironji seed study used it to measure gallic acid, chlorogenic acid, caffeic acid, rutin and quercetin. A reliable workflow includes a quercetin stock standard, several calibration levels, a calibration curve, filtered plant samples, retention-time comparison and, ideally, spectral confirmation. Retention time depends on the method and should not be assumed to be identical across laboratories.

14. Total Phenolic and Total Flavonoid Content

14.1 Total phenolic content

The Folin-Ciocalteu assay is widely used to estimate total phenolic content. Gallic acid is usually the calibration standard, and results are expressed as mg gallic acid equivalents (GAE) per g of extract. Because other reducing substances can react in the assay, it is not entirely specific for phenolics.

14.2 Total flavonoid content

The aluminium chloride colorimetric assay is commonly used for total flavonoid estimation, often with quercetin as the reference standard. Results may be reported as mg quercetin equivalents (QE) per g of extract. A total flavonoid value does not show that all flavonoids present are quercetin; individual quercetin measurement requires chromatography.

15. Biological Activities of Chironji Seed Extracts

Recent findings indicate that Chironji seed extracts have considerable biological activity. The 2024 Food Bioscience study reported antioxidant, antidiabetic and anticholinesterase effects and related these findings to the seed's phytochemical composition. The hydroalcoholic extract performed well in DPPH, ORAC and CAP-e antioxidant assays. The study also examined alpha-amylase, alpha-glucosidase, acetylcholinesterase and butyrylcholinesterase inhibition.

Table 6. Selected biological effects reported for B. lanzan

Activity	Approach
Antioxidant	DPPH, ORAC and CAP-e assays
Antidiabetic potential	α -Amylase and α -glucosidase inhibition
Anticholinesterase	AChE and BChE inhibition
Anti-inflammatory potential	Reported in traditional and pharmacological literature
Antimicrobial potential	Reported in phytopharmacological studies
Nutraceutical potential	Nutritional and antioxidant characterization

Biological activity observed for a crude extract cannot be attributed to quercetin alone. Chironji contains many phenolics, flavonoids, fatty acids and other constituents that may contribute. Chromatographic standardization is valuable because it makes it easier to relate individual markers to observed activity.

16. Pharmaceutical Cocrystallization

A pharmaceutical cocrystal is a crystalline material made from an active pharmaceutical ingredient and another molecular component, called a coformer, arranged in a defined lattice. Unlike a conventional salt, a cocrystal may be held together mainly by nonionic interactions such as hydrogen

bonding, pi-pi interactions and van der Waals forces. Pharmaceutical cocrystals are being investigated to alter solubility, dissolution, stability, mechanical behaviour and pharmacokinetics.

17. Quercetin Cocrystallization

Quercetin's low solubility partly reflects strong intermolecular interactions and crystal packing. Introducing a coformer can reorganize that packing and create new hydrogen-bonding patterns. Depending on the system, this may reduce effective lattice stability, change melting behaviour and improve dissolution or apparent solubility. Improvement is not guaranteed, however: the thermodynamic relationship among the cocrystal, its components and the solvent must be examined. Physical-mixture controls are essential for interpretation.

18. Quercetin–Nicotinamide Cocrystals: Direct Literature Evidence

Wu and colleagues provided one of the most relevant examples for this topic in their study of quercetin-nicotinamide cocrystals. They used solvent evaporation, combining the components at 1:1 and 1:2 molar ratios in absolute ethanol at 80 C, followed by filtration and slow evaporation at room temperature. FTIR, PXRD and DSC were used for characterization. The PXRD patterns differed from those of the separate materials and their physical mixture, supporting the formation of new crystalline phases, while FTIR indicated intermolecular hydrogen bonding. The cocrystals dissolved substantially better than quercetin crystals and increased oral absorption by about four-fold in the reported animal study.

19. Other Potential Coformers

Table 7. Potential coformers for quercetin

Coformer	Applications
Nicotinamide	Strong hydrogen-bonding functionality; demonstrated quercetin cocrystal system
Urea	Multiple hydrogen-bond donor/acceptor sites
Citric acid	Multiple hydrogen-bonding groups
Tartaric acid	Multiple hydrogen-bond donors/acceptors
Succinic acid	Simple organic acid suitable for crystal engineering
Malic acid	Multiple interaction sites

Terms such as acidic, neutral and basic should be used with care in cocrystal studies. pKa is not the only consideration; solid-state interactions, molecular complementarity, stoichiometry and the possibility of salt formation all need to be assessed experimentally.

20. Cocrystal Preparation Methods

20.1 Solvent evaporation

In solvent evaporation, the API and coformer are dissolved in a common solvent or solvent mixture and allowed to crystallize as the solvent is removed in a controlled way. The method is simple, useful for screening and allows crystals to be collected easily. The quercetin-nicotinamide system is a direct example.

20.2 Liquid-assisted grinding

Liquid-assisted grinding uses mechanical mixing of the API and coformer with a very small amount of liquid. It uses little solvent, is quick, and is particularly useful for screening combinations with limited solubility.

20.3 Slurry conversion

For slurry conversion, the API and coformer are suspended in a solvent in which their solubilities are controlled. With sufficient equilibration, the system may convert to a more stable multicomponent crystalline form.

20.4 Neat grinding

Neat grinding brings the components together mechanically without a solvent. It is attractive from a green-chemistry perspective, although grinding time, energy and stoichiometry often need careful optimization.

21. Characterization of Quercetin Cocrystals

21.1 Powder X-ray diffraction

PXRD is one of the key tools for showing that a new crystalline phase has formed. A genuine cocrystal should give a diffraction pattern that is not simply the combined pattern of the parent API and coformer.

21.2 Differential scanning calorimetry

DSC provides information on melting, thermal events, decomposition and phase changes. A new thermal event can support cocrystal formation, but DSC by itself is not conclusive proof.

21.3 FTIR spectroscopy

FTIR can reveal changes in hydrogen-bonding environments through shifts in O-H, C=O and other characteristic bands. A shifted FTIR peak alone, however, is insufficient to establish a new cocrystal.

21.4 Scanning electron microscopy

SEM can be used to compare crystal morphology, particle shape and surface features.

21.5 HPLC

HPLC is useful for measuring quercetin content, chemical purity, possible degradation and, where needed, the API-to-coformer composition.

22. Future Perspectives

Future studies should move beyond basic extraction and qualitative screening. Chironji accessions should be compared, since recent studies show variation in nutritional and bioactive properties. Extraction can be optimized through designed experiments that examine ethanol concentration, solid-to-solvent ratio, time and temperature. For quality control, chromatographic fingerprints should include quercetin as one marker alongside gallic acid, chlorogenic acid, caffeic acid and rutin. Cocrystal screening should cover several coformers and stoichiometric ratios, and computational tools such as hydrogen-bond propensity and molecular complementarity may help guide selection. Characterization must extend beyond FTIR: PXRD is essential to establish a new crystalline phase. In addition, faster dissolution should not automatically be taken as evidence of improved bioavailability.

23. Conclusion

Buchanania lanzan Spreng. is a nutritionally valuable yet comparatively underused medicinal plant. Its seeds contain substantial nutrients as well as a diverse range of phenolic and flavonoid constituents. Modern analytical studies have confirmed quercetin, gallic acid, chlorogenic acid,

caffeic acid and rutin in Chironji seed-kernel extracts. Quercetin is an appealing natural flavonol because of its broad biological research profile, but poor aqueous solubility and limited oral bioavailability remain major obstacles. Nanoparticles, lipid-based delivery systems, cyclodextrin complexes and pharmaceutical cocrystals are among the approaches being explored to overcome them.

Cocrystallization is useful because it can alter crystal packing and other solid-state properties without changing the active molecule covalently. The quercetin-nicotinamide system shows that a new crystalline phase can improve dissolution and increase oral absorption in an experimental setting. For Chironji-based work, the stronger and more defensible contribution is not to rediscover quercetin, but to standardize its extraction and enrichment from Chironji and then develop natural-coformer cocrystals systematically. A study that combines HPTLC or HPLC standardization with PXRD, FTIR, DSC, SEM and comparative dissolution testing may provide a useful link between natural-products chemistry and pharmaceutical crystal engineering.

24. Reference:

1. Yadav, A., Jha, S., Ram, A., Yadav, V., Anuragi, H., Choudhary, G., Yadav, R., Sandeep, G. P., Garg, S., Dev, I., Kumar, N., Handa, A. K., & Arunachalam, A. (2026). Comprehensive profiling of indigenous chironji (*Buchanania lanzan* Spreng.) accessions for antioxidant, antidiabetic, nutritional properties, and seed oil for pharmaceutical use and livelihood development. *Journal of Agriculture and Food Research*, 26. <https://doi.org/10.1016/j.jafr.2026.102734>
2. Mondal, M., Konar, A., Halder, S., Roy, A., Dalal, D. das, & Ghosh, P. (2024). An insight into the morphological, ethno medicinal, phytochemical and pharmaceutical properties of *Buchanania lanzan*. *Journal of Medicinal Plants Studies*, 12(1), 11–17. <https://doi.org/10.22271/plants.2024.v12.ila.1620>
3. Roshani, O. A., Vyavaharkar, Y., & Mangaonkar, S. S. (2016). *EXTRACTION OF FLAVONOIDS FROM BUCHANANIA LANZAN SPRENG. SEEDS BY SUPERCRITICAL FLUID EXTRACTION AND DETERMINATION OF THEIR ANTIOXIDANT ACTIVITY*.
4. Mann, S., Tushir, S., Kaur, G., Samandeep, Devi, T. B., Sethi, S., Sahu, N., Bala, M., Vishwakarma, R. K., & Kotwaliwale, N. (2025). Harnessing the potential of underutilised *Buchanania lanzan* Spreng.: Review on processing, nutrition, and applications. *Indian Journal of Natural Products and Resources*, 16(4), 554–567. <https://doi.org/10.56042/ijnpr.v16i4.17124>
5. Tzanova, M., Atanasov, V., Yaneva, Z., Ivanova, D., & Dinev, T. (2020). Selectivity of current extraction techniques for flavonoids from plant materials. In *Processes* (Vol. 8, Issue 10, pp. 1–30). MDPI AG. <https://doi.org/10.3390/pr8101222>
6. Khatoon, N., Gupta, R. K., & Tyagi, Y. K. (2015). Nutraceutical potential and phytochemical screening of *Buchanania lanzan*, an underutilized exotic Indian nut and its use as a source of functional food. ~ 87 ~ *Journal of Pharmacognosy and Phytochemistry*, 4(1).
7. Jatav, P., & Kumar Tenguria, R. (n.d.). (Vol. 2023). Qualitative Analysis of Phytoconstituents of *Buchanania lanzan* Leaf Extracts. In *Eur. Chem. Bull*.
8. Singh Rajput, B., Gupta, D., Kumar, S., Singh, K., Tiwari, C., & Bhalendra Singh Rajput, C. (2018). *Buchanania lanzan* Spreng (*Chironji*): A vulnerable multipurpose tree species in

- Vindhyan region. ~ 833 ~ *Journal of Pharmacognosy and Phytochemistry*, 7(5). www.zauba.com/export-
9. Kumar Tripathi, M., Kumar, A., Chandranshu Mishra, M., Singh, R., & Gandhi Chitrakoot Gramodaya, M. (2016). *PRELIMINARY PHYTOCHEMICAL INVESTIGATION AND PHARMACOGNOSTIC STUDY OF SEEDS OF BUCHANANIA LANZAN SPRENG* (Vol. 334, Issue 2). www.indianbotsoc.org
 10. Meher N, Kisan B, Swain SK, Sahoo AK. (2024) Industrial importance seed kernel of *Buchanania lanzan* in contributing antioxidant, antidiabetic, and anticholinesterase activities. *Food Biosci.* <https://doi.org/10.1016/j.fbio.2024.104135>.
 11. Kim, J. K., & Park, S. U. (2018). Quercetin and its role in biological functions: An updated review. In *EXCLI Journal* (Vol. 17, pp. 856–863). Leibniz Research Centre for Working Environment and Human Factors. <https://doi.org/10.17179/excli2018-1538>
 12. Cai, X., Fang, Z., Dou, J., Yu, A., & Zhai, G. (2013). Send Orders of Reprints at reprints@benthamscience.net Bioavailability of Quercetin: Problems and Promises. In *Current Medicinal Chemistry* (Vol. 20).
 13. Alizadeh SR, Savadkouhi N, Ebrahimzadeh MA. (2023) Drug design strategies that aim to improve the low solubility and poor bioavailability conundrum in quercetin derivatives. *Expert Opin Drug Discovery*, 18(10):1117–1132. doi:10.1080/17460441.2023.2241366
 14. Thakuria, R., Delori, A., Jones, W., Lipert, M. P., Roy, L., & Rodríguez-Hornedo, N. (2013). Pharmaceutical cocrystals and poorly soluble drugs. In *International Journal of Pharmaceutics* (Vol. 453, Issue 1, pp. 101–125). Elsevier B.V. <https://doi.org/10.1016/j.ijpharm.2012.10.043>
 15. Guo M, Sun X, Chen J, Cai T. (2021) Pharmaceutical cocrystals: a review of preparations, physicochemical properties and applications. *Acta Pharm Sin B.*,11(8):2537–2564. doi:10.1016/j.apsb.2021.03.030
 16. Wu, N., Zhang, Y., Ren, J., Zeng, A., & Liu, J. (2020). Preparation of quercetin-nicotinamide cocrystals and their evaluation underin vivoandin vitroconditions. *RSC Advances*, 10(37), 21852–21859. <https://doi.org/10.1039/d0ra03324c>
 17. Good, D. J., & Naír, R. H. (2009). Solubility advantage of pharmaceutical cocrystals. *Crystal Growth and Design*, 9(5), 2252–2264. <https://doi.org/10.1021/cg801039j>
 18. Thipparaboina, R., Kumar, D., Chavan, R. B., & Shastri, N. R. (2016). Multidrug co-crystals: Towards the development of effective therapeutic hybrids. In *Drug Discovery Today* (Vol. 21, Issue 3, pp. 481–490). Elsevier Ltd. <https://doi.org/10.1016/j.drudis.2016.02.001>
 19. Harborne JB. (1998). *Phytochemical Methods: A Guide to Modern Techniques of Plant Analysis*. 3rd ed. London: Chapman and Hall.
 20. Sultana, B., & Anwar, F. (2008). Flavonols (kaempferol, quercetin, myricetin) contents of selected fruits, vegetables and medicinal plants. *Food Chemistry*, 108(3), 879–884. <https://doi.org/10.1016/j.foodchem.2007.11.053>
 21. Karimi-Jafari, M., Padrela, L., Walker, G. M., & Croker, D. M. (2018). Creating cocrystals: A review of pharmaceutical cocrystal preparation routes and applications. In *Crystal Growth and Design* (Vol. 18, Issue 10, pp. 6370–6387). American Chemical Society. <https://doi.org/10.1021/acs.cgd.8b00933>

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22. Biscaia, I. F. B., Oliveira, P. R., Gomes, S. N., & Bernardi, L. S. (2021). Obtaining cocrystals by reaction crystallization method: Pharmaceutical applications. In *Pharmaceutics* (Vol. 13, Issue 6). MDPI. <https://doi.org/10.3390/pharmaceutics13060898>