Review article

Quisqualis indica: A critical review of phytochemicals, therapeutic potential, and translational challenges

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Abstract

Quisqualis indica L. is a promising medicinal plant due to its diverse pharmacological activities and phytochemical composition. Although it has long been used in Asian and African ethnomedicine to treat gastrointestinal issues, metabolic problems, parasite infections, and inflammatory disorders, current research on its therapeutic potential is fragmented and methodologically inconsistent. This review critically evaluates the current literature on the phytochemistry, pharmacological activities, and therapeutic potential of *Q. indica*, focusing on the mechanistic functions of the plant's main bioactive components, flavonoids, polyphenols, tannins, cucurbitacin derivatives, trigonelline, and quisqualic acid. A systematic literature search following PRISMA 2020 guidelines was conducted using PubMed/MEDLINE, Scopus, Web of Science, and Google Scholar (database inception to 30 June 2026). Of 642 records identified, 154 duplicates were removed; 488 records were screened, 140 full-text articles were assessed for eligibility, and 76 studies were ultimately included in the qualitative synthesis. Experimental results show that *Q. indica* has significant antioxidant, anticancer, antibacterial, anti-inflammatory, antimalarial, anti-obesity, and neuropharmacological activities by regulating oxidative stress, apoptosis, inflammatory mediators, microbial growth, and metabolic signalling pathways. However, a detailed evaluation of the existing data finds severe flaws, such as insufficient phytochemical standardisation, inconsistent extraction methodologies, an overreliance on *in vitro* and animal models, and a scarcity of quality clinical trials. A paucity of evidence on pharmacokinetics, bioavailability, long-term toxicity, and herb-drug interactions further limits translational applicability. Despite these limitations, combining advanced analytical techniques, nanotechnology-based delivery technologies, and mechanism-driven pharmacological research may enhance the therapeutic potential of compounds obtained from *Q. indica*. Overall, this review stresses *Q. indica*'s therapeutic significance while highlighting significant research gaps that must be addressed before its bioactive constituents can be translated into evidence-based phytopharmaceutical medicines.

Keywords: *Quisqualis indica*; phytochemicals; flavonoids; pharmacological activities; natural drug development; antioxidant and anticancer potential.

1. Introduction

Medicinal plants continue to play an indispensable role in healthcare and drug discovery, providing structurally diverse natural products that serve as important sources of therapeutic agents. More than 80% of the global population relies, at least partially, on traditional herbal medicines for primary healthcare, and approximately one-quarter of currently approved pharmaceuticals are directly or indirectly derived from plant metabolites (Bezerra *et al.*, 2020; Christaki *et al.*, 2012; Christaki *et al.*, 2020; Dixit *et al.*, 2023; Garcia-Oliveira *et al.*, 2021; Herzyk *et al.*, 2024; Samy *et al.*, 2008; Shrinet *et al.*, 2021; Sun & Shahrajabian, 2023). Consequently, medicinal plants remain an important focus of phytochemical and pharmacological research aimed at identifying novel bioactive compounds with improved efficacy and safety.

Quisqualis indica L. (syn. *Combretum indicum* L.), commonly known as Rangoon creeper, is a perennial woody climber belonging to the family Combretaceae (**Figure 1**). The species is native to tropical Asia and is widely distributed throughout India, China, Bangladesh, Sri Lanka, Thailand, Malaysia, and other Southeast Asian countries. Besides its ornamental value owing to its fragrant flowers that change colour from white to pink and deep red during maturation, *Q. indica* has long been utilized in Ayurvedic, Traditional Chinese Medicine, and other indigenous healthcare systems. Different parts of the plant, including the leaves, flowers, fruits, seeds, bark, stems, and roots, have traditionally been used for the management of intestinal helminthiasis, diarrhoea, fever, skin infections, inflammation, rheumatism, parasitic diseases, and gastrointestinal disorders (Boy *et al.*, 2018; Eisikowitch & Rotem, 1987; Jahan *et al.*, 2008; Kim *et al.*, 2026; Kulshreshtha *et al.*, 2018; Lin *et al.*, 1997; Patel & Patel, 2020; Rastogi R, 1990; Rastogi *et al.*, 1993; Sharma *et al.*, 2024; Yan *et al.*, 2018).

Plant profile

Botanical Name: *Q. indica Linn*.
Local Names: English (Rangoon Creeper),
Hindi (Madhumalti)
Kingdom: Plantae
Division: Magnoliophyta
Class: Magnoliopsida
Order: Myrtales
Family: Combretaceae
Genus: *Quisqualis*
Species: *Q.indica* (Verma & Rawat, 2025).

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Figure 1. *Quisqualis indica* L. Pers.

Phytochemical investigations have demonstrated that *Q. indica* is a rich reservoir of biologically active secondary metabolites. The plant contains flavonoids (kaempferol, quercetin, rutin and luteolin) (**Figure 2**), phenolic compounds, tannins, cucurbitacin derivatives, alkaloids including quinoline-4-carbonitrile, trigonelline, glycosides, amino acids, fatty acids and the neuroactive amino acid quisqualic acid (Jahan *et al.*, 2008; Kulshreshtha *et al.*, 2018; Nemade & Aher, 2024; Romano *et al.*, 2013; Tsao & McCallum, 2009; Verma & Rawat, 2025; Yan *et al.*, 2018). These phytochemicals contribute collectively to the diverse biological activities reported for the plant, including antioxidant, anti-inflammatory, antimicrobial, anticancer, antimalarial, anti-obesity, antiparasitic, neuropharmacological and hepatoprotective effects. Rather than being attributed to a single constituent, these pharmacological effects are believed to arise from synergistic interactions among multiple phytochemicals that modulate oxidative stress, inflammatory signalling, apoptosis, microbial growth and metabolic pathways (Boy *et al.*, 2018; Hassanpour & Doroudi, 2023; Havsteen, 2002; Jaganath & Crozier, 2009; Kulshreshtha *et al.*, 2018; Manthey, 2000; Nemade & Aher, 2024; P.M *et al.*, 2026; Peterson & Dwyer, 1998; Romano *et al.*, 2013; Sharma *et al.*, 2024; Tsao & McCallum, 2009; Verma & Rawat, 2025; Yan *et al.*, 2018).

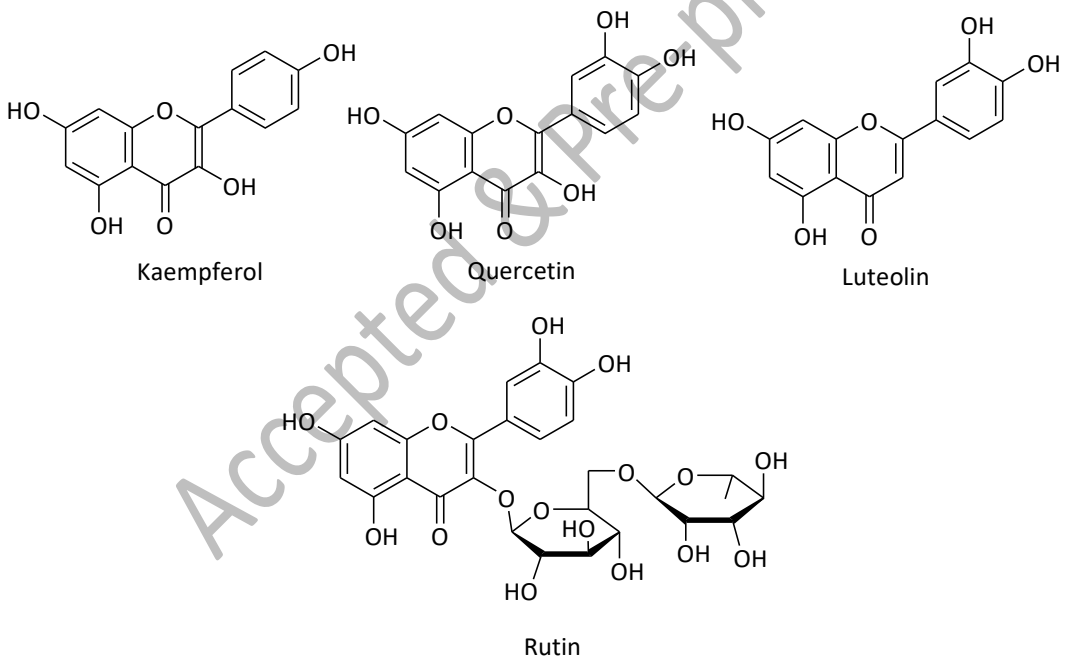

Figure 2. Representative flavonoid constituents of *Quisqualis indica*. Chemical structures of kaempferol, quercetin, luteolin, and rutin, highlighting the principal flavonoids reported from the plant and their relevance to its pharmacological properties.

Among the identified phytochemicals, flavonoids and other phenolic constituents have attracted considerable scientific interest because of their antioxidant and anti-inflammatory properties and their ability to regulate cellular signalling pathways involved in carcinogenesis, oxidative stress and immune responses (Dashwood, 2007; Hassanpour & Doroudi, 2023; Havsteen, 2002; Jaganath & Crozier, 2009; Kumar & Pandey, 2013; Linseisen & Rohrmann, 2008; Manthey, 2000; Peterson & Dwyer, 1998; Romano *et al.*, 2013; Rothwell *et al.*, 2017; Tsao & McCallum, 2009; Wang *et al.*, 2015; Wu *et al.*, 2020; Yan *et al.*, 2018). However, these compounds represent only one component of the complex phytochemical profile of *Q. indica*. Other metabolites, including cucurbitacin derivatives, quinoline alkaloids and quisqualic acid, have also demonstrated important pharmacological activities, suggesting that the therapeutic potential of the plant depends on its overall phytochemical diversity rather than on flavonoids alone (Jahan *et al.*, 2008; Kulshreshtha *et al.*, 2018; Rastogi R, 1990).

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During the past two decades, numerous *in vitro*, *in vivo* and phytochemical investigations have explored the medicinal potential of *Q. indica*. Experimental studies have demonstrated cytotoxic activity against several cancer cell lines, potent antioxidant and antibacterial effects, larvicidal activity against mosquito vectors, beneficial effects in testosterone-induced benign prostatic hyperplasia, and neuropharmacological actions associated with quisqualic acid (Boušová & Skálová, 2012; Caltagirone *et al.*, 2000; Farhan *et al.*, 2023; González-Sarrías *et al.*, 2020; Kawata *et al.*, 1996; Liu *et al.*, 2021; Majdan & Bobrowska-Korczak, 2022; Monici *et al.*, 1993; Smith *et al.*, 2000; Soto-Vaca *et al.*, 2012; Taylor & Grotewold, 2005; Weston & Mathesius, 2013; Winkel-Shirley, 2002). Nevertheless, the available evidence remains fragmented because studies differ considerably in plant part investigated, extraction methods, phytochemical characterization, experimental models and outcome measures, making direct comparison difficult.

Despite increasing scientific interest in *Q. indica*, the available evidence on its phytochemical composition, pharmacological activities, molecular mechanisms, and therapeutic applications remains dispersed across individual experimental studies. Existing reviews primarily provide descriptive summaries and do not comprehensively evaluate the current evidence using a systematic methodology. Moreover, the translational challenges associated with standardization, safety evaluation, bioavailability, and future pharmaceutical development have received limited attention. Therefore, the present systematic review was conducted in accordance with the PRISMA 2020 guidelines to critically synthesize the available evidence on the phytochemical constituents, pharmacological activities, mechanisms of action, and translational potential of *Q. indica*, while identifying current knowledge gaps and future research priorities.

2. Methods

This review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines to ensure transparency and reproducibility in the literature selection process. A systematic search of PubMed, Scopus, Web of Science, and Google Scholar was performed from database inception to 30 June 2026. The search strategy combined Medical Subject Headings (MeSH) and free-text keywords using Boolean operators, including "*Quisqualis indica*" OR "Rangoon creeper" OR "Combretaceae" AND phytochemistry OR phytochemicals OR pharmacological activity OR antioxidant OR anticancer OR antibacterial OR anti-inflammatory OR neuropharmacology OR quisqualic acid (Moher *et al.*, 2009; Moher *et al.*, 2010; Page *et al.*, 2021; Page *et al.*, A declaração PRISMA 2020: diretriz atualizada para relatar revisões sistemáticas./2022).

The retrieved records were imported into a reference management system, and duplicate records were removed before screening. Two-stage screening was performed by evaluating titles and abstracts followed by full-text assessment. Studies were included if they reported phytochemical characterization, pharmacological, toxicological, mechanistic, or therapeutic investigations of Quisqualis indica published in peer-reviewed journals. Conference abstracts, editorials, duplicate publications, review articles, studies lacking sufficient experimental data, and non-English publications were excluded.

The literature search identified 642 records. After removal of 154 duplicate records, 488 articles remained for title and abstract screening. Following screening, 348 articles were excluded because they did not meet the inclusion criteria. The full texts of 140 articles were assessed for eligibility, and 64 articles were excluded owing to insufficient experimental data, irrelevance to the review objectives, duplicate information, or publication type. Finally, 76 studies were included in the qualitative synthesis. The complete study selection process is illustrated in the PRISMA 2020 flow diagram (**Figure 3**) (Chigbu *et al.*, 2023; Gough *et al.*, 2012; Hammersley, 2001; Kitchenham *et al.*, 2010; Wohlin *et al.*, 2012).

The data from the selected papers were rigorously extracted, including authorship, publication year, study design, plant component studied, extraction methods, isolated chemicals, experimental models, pharmacological assays, and key findings. The extracted data were then qualitatively synthesised to provide a comprehensive overview of *Q. indica*'s chemical composition, biological activities, and potential therapeutic applications, with a focus on the neuroactive compound quisqualic acid and its role in pharmacological and neuroscientific research. The Cochrane Handbook for Systematic Reviews of Interventions, created by the Cochrane Collaboration, provided methodological suggestions for evidence interpretation and synthesis, enabling an organised and unbiased examination of the available literature (Frost *et al.*, 2022; Grant & Booth, 2009; Lunny *et al.*, 2017; Stewart *et al.*, 2015; Tugwell & Tovey, 2021).

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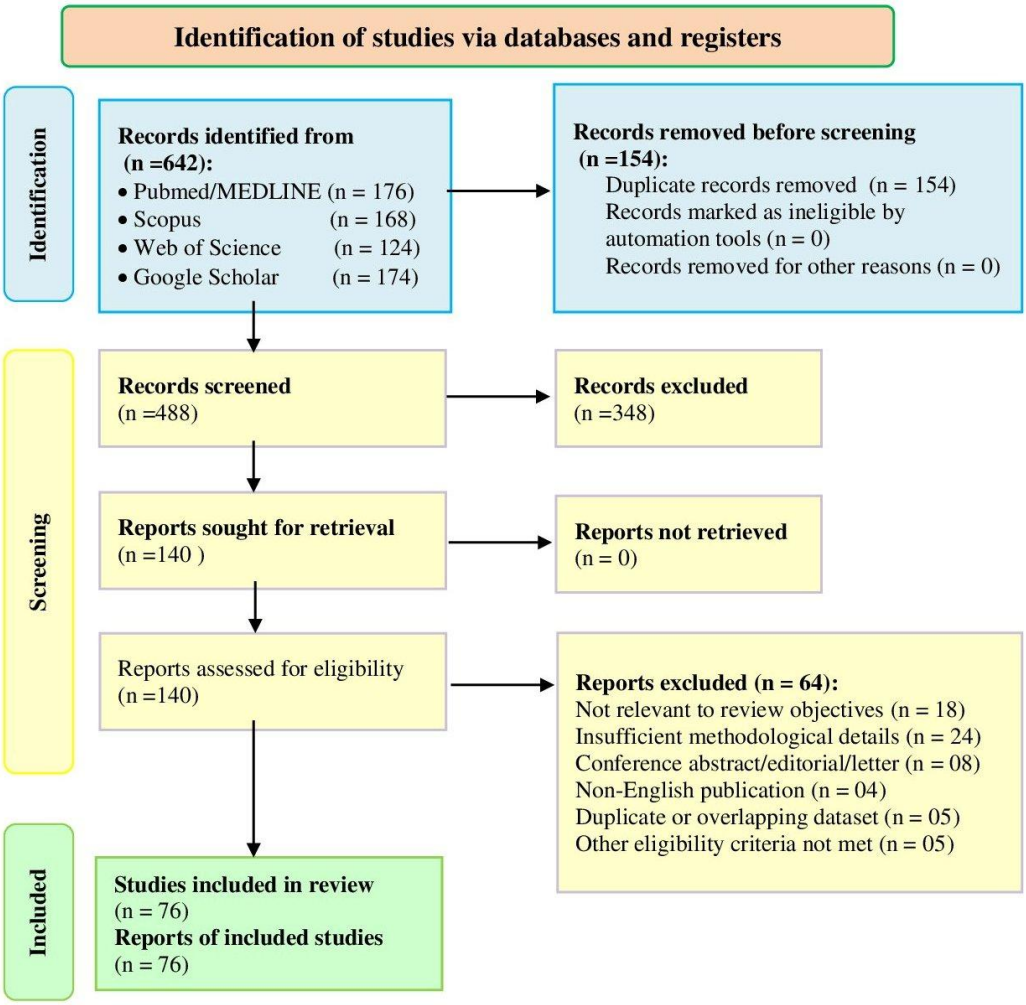

Figure 3. PRISMA 2020 flow diagram illustrating the study identification, screening, eligibility assessment, and inclusion process for the systematic review. A total of 642 records were identified through electronic database searches (PubMed/MEDLINE, Scopus, Web of Science, and Google Scholar). After removing 154 duplicate records, 488 records were screened, of which 350 were excluded based on title and abstract. Following full-text assessment of 138 reports, 64 were excluded according to the predefined eligibility criteria, resulting in the inclusion of 76 studies in the qualitative synthesis.

3. Literature Review

3.1. Chemistry of *Quisqualis indica*

Quisqualis indica L. contains diverse phytochemicals, including flavonoids, phenolics, tannins, cucurbitacin derivatives, alkaloids, glycosides, amino acids, fatty acids, and organic acids. Major reported constituents include kaempferol, quercetin, rutin, luteolin, 25-O-acetyl-23,24-dihydrocucurbitacin F, quinoline-4-carbonitrile, quisqualic acid, and trigonelline (Jahan *et al.*, 2008; Kulshreshtha *et al.*, 2018; Lin *et al.*, 1997; Rout *et al.*, 2021; Verma & Rawat, 2025).

The phytochemical profile varies with plant part and extraction method. Flavonoids and phenolics are mainly reported from leaves, flowers, and fruits, whereas cucurbitacin derivatives occur in leaves and twigs, and quisqualic acid and trigonelline are associated primarily with seeds (Efferth *et al.*, 2008; Lohberger *et al.*, 2015; Wijerathne *et al.*, 2017). Differences in aqueous, ethanolic, methanolic, chloroform, dichloromethane, and hydrodistilled extracts further influence the constituents recovered and may contribute to variations in reported biological activities (Afify & Hassan, 2016; Jahan *et al.*, 2009; Rout *et al.*, 2021).

Although chromatographic and spectrometric techniques have identified several constituents, phytochemical standardization remains inconsistent. Therefore, validated HPLC, LC–MS/MS, GC–MS, and quantitative fingerprinting are required to establish reproducible chemical profiles and meaningful chemical–activity relationships (Kulshreshtha *et al.*, 2018; Verma & Rawat, 2025). The distribution of the major phytochemicals across different plant parts and their reported

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biological activities is summarized in **Table 1**, highlighting the chemical basis underlying the observed pharmacological heterogeneity.

Table 1. Major phytochemical classes identified in Quisqualis indica, including their principal compounds, plant sources, extraction solvents or analytical methods, reported biological activities, evidence level, and corresponding references.

Phytochemical Class	Major Compounds Identified	Plant Part	Extraction Solvent / Analytical Method	Reported Biological Activities	Evidence Level	Citation
Flavonoids	Kaempferol, Quercetin, Rutin, Luteolin	Leaves, Flowers, Fruits	Methanolic and ethanolic extracts; chromatographic analysis (HPLC/LC–MS where reported)	Antioxidant, anti-inflammatory, anticancer activities	*In vitro*	(Arai *et al.*, 2000; Kumar & Pandey, 2013; Majdan & Bobrowska-Korczak, 2022; Verma & Rawat, 2025)
Polyphenols	Phenolic acids and related polyphenols	Leaves, Flowers	Ethanol, hydroethanolic and aqueous extracts	Free radical scavenging, protection against oxidative stress	*In vitro*	(Rothwell *et al.*, 2017; Wang *et al.*, 2015)
Tannins	Hydrolysable and condensed tannins	Bark, Leaves	Solvent extraction; phytochemical isolation (solvent NR in some studies)	Antimicrobial and antioxidant activities	*In vitro*	(Lin *et al.*, 1997)
Alkaloids	Quinoline-4-carbonitrile (QCN)	Flowers	Hydrodistilled floral extract; GC–MS analysis	Antioxidant and anti-inflammatory activities	*In vitro*	(Rout *et al.*, 2021)
Cucurbitacin Derivatives	25-O-acetyl-23,24-dihydro-cucurbitacin F	Leaves and Twigs	Purified isolated compound	Cytotoxic and anticancer activity against tumour cell lines	*In vitro*	(Efferth *et al.*, 2008; Birgit Lohberger *et al.*, 2015)
Amino Acids	L-Proline, L-Asparagine	Leaves	Phytochemical profiling (method NR)	Plant metabolism; potential physiological activities	Phytochemical evidence	(Rastogi R, 1990)
Glycosides	Cyanogenic glycosides and other glycosides	Flowers, Fruits	Solvent extraction (NR)	May contribute to plant defence and biological activity	Phytochemical evidence	(Lin *et al.*, 1997; Rastogi R, 1990)
Organic Acids	Succinic acid, Citric acid, Malic acid	Bark	Phytochemical profiling (method NR)	Potential antioxidant and metabolic functions	Phytochemical evidence	(Rastogi R, 1990)
Fatty Acids	Palmitic acid, Oleic acid, Linoleic acid, Myristic acid	Seeds	Oil fraction analysis (GC-based analysis where reported)	Nutritional and anti-inflammatory properties	Phytochemical evidence	(Rastogi R, 1990)
Other Bioactive Compounds	Quisqualic acid, Trigonelline	Seeds, Leaves	Ethanolic extract and phytochemical isolation	Neuropharmacological activity and metabolic regulation	Combined preclincal	(Rastogi R, 1990; Wijerathne *et al.*, 2017)

Abbreviations: GC–MS, gas chromatography–mass spectrometry; HPLC, high-performance liquid chromatography; LC–MS, liquid chromatography–mass spectrometry; NR, not reported; QCN, quinoline-4-carbonitrile.

The structural diversity of *Q. indica* metabolites provides a plausible basis for its broad pharmacological profile. Flavonoids and phenolics are mainly associated with antioxidant and anti-inflammatory effects, while cucurbitacin derivatives, quinoline alkaloids, and seed-associated metabolites contribute additional anticancer, antimicrobial, metabolic, and neuropharmacological potential (Efferth *et al.*, 2008; B. Lohberger *et al.*, 2015; Rout *et al.*, 2021; Wijerathne *et al.*, 2017). However, most associations remain preclinical and require further chemical standardization and mechanistic validation.

The major bioactive constituents responsible for these pharmacological effects are illustrated in **Figure 4**, which highlights the structural diversity of the principal phytochemicals identified in *Q. indica*.

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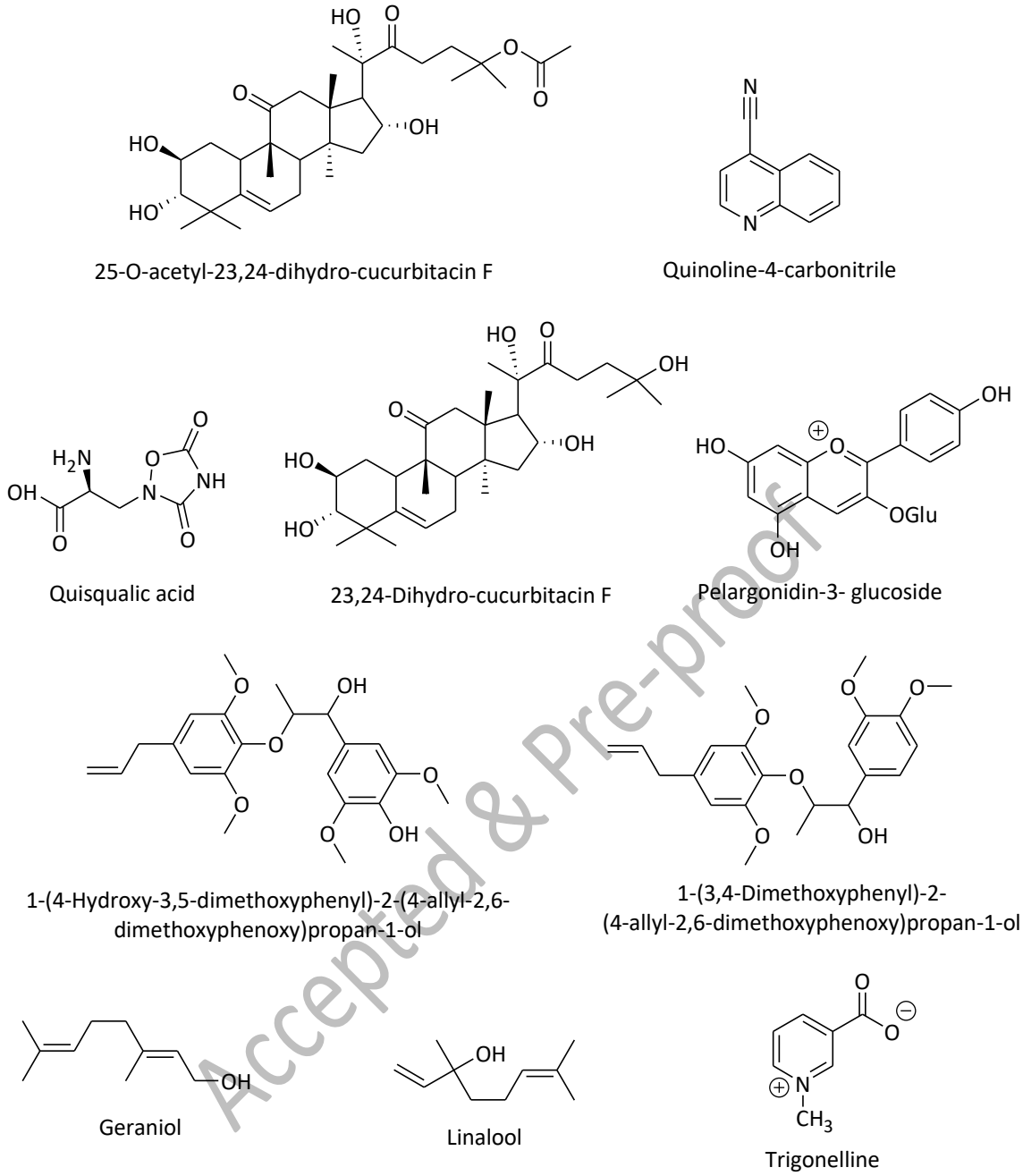

Figure 4. Representative phytochemicals reported from Quisqualis indica. The illustrated compounds include 25-O-acetyl-23,24-dihydrocucurbitacin F, quinoline-4-carbonitrile, quisqualic acid, 23,24-dihydrocucurbitacin F, pelargonidin-3-O-glucoside, two lignan derivatives [1-(4-hydroxy-3,5-dimethoxyphenyl)-2-(4-allyl-2,6-dimethoxyphenoxy)propan-1-ol and 1-(3,4-dimethoxyphenyl)-2-(4-allyl-2,6-dimethoxyphenoxy)propan-1-ol], geraniol, linalool, and trigonelline. These metabolites belong to multiple phytochemical classes associated with the medicinal properties of the plant.

3.2. Anticancer activity

Efferth *et al.* (2008) were researching how chemotherapy slows down the growth of the drug. Natural products offer potential solutions. They contain the bioactive substances 25-*O*-acetyl-23,24-dihydro-cucurbitacin F from *Q. indica* and miltenirone from Salvia miltenirrhiza. The effectiveness of miltirone was correlated with gene expression in 60 tumour stem cell lines (Efferth *et al.*, 2008).

Kim *et al.* (2020) study looked at the symptom-correcting properties of a sacred blood extract in a rat model. Following administration of testosterone propionate (TP) to rats, the basal intraurethral pressure (IUP) and the increase in IUP

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following stimulation of the electrical field (5 V, 5, 10, or 20 Hz) with either testosterone (0.01, 0.03, 0.1 mg) or phenylephrine (Phenylephrine) were measured. BPH was induced by daily injections of topical testosterone (3 mg/kg) administered intravenously to immature rats. The first treatment group received laxatives (10 mg/kg bodyweight) while the second group received laxatives with a laxative component (secretin) (Kim *et al.*, 2020).

Lohberger *et al.* (2015) investigated the effects of 25-*O*-acetyl-23,24-dihydrocurbitacin F (1) on cell viability, cell division, and apoptosis in three human sarcoma cell lines: SW-872, SW-982, and TE-671, using three different cell proliferation assays: CellTiter 96, Aqueous One Solution, RT-PCR, Western blot, and Caspase-3,3,7. Their findings suggest that 25-O-acetyl-23,24-dihydro-cucurbitacinF causes a dose-dependent decline in cell viability and induces a halt in the cell cycle at the G2/M checkpoint. This G2M arrest was associated with a decrease in the expression of key cytokines, such as cyclin B1, cyclin A, cyclin B2, and cyclin B3. In addition, the secretion of survival factor, a key protein involved in regulating mitosis and apoptosis, was significantly reduced by 25-O-acetyl-23,24-dihydroxy-cucurbitacin F (Birgit Lohberger *et al.*, 2015).

Mukhopadhyay *et al.* (2018) extracted from *Q. indica* is rich in polyphenols with strong antioxidant properties, which are essential for reducing and stabilising copper nanoparticles. In their study, melanoma cells B16F10 and normal (NIH3T3) fibroblasts were exposed to different concentrations of quinine (40-120 mg per ml) and flower extract (PE) for 24 hours at a total of 40 to 500 mg per ml. Cytotoxicity was evaluated by determining the percentage viability of the cells divided by the average daily workload. They found that QCuNPs exhibit concentration-dependent cytotoxicity with an IC50 of 102 mg per ml in B16F10 cells, while more than 80 mg of QCuNPs per ml maintained viability in Nih3T3 cells. Therefore, the toxicity levels were minimal in normal cell lines (Mukhopadhyay *et al.*, 2018).

Wijerathne *et al.* (2017) investigated the therapeutic potential of a 70% ethanol extract from *Q. indica* seed for the treatment of benign prostatic hyperplasia (BPH). They conducted experiments using a human LNCaP prostate cancer cell line and a rat template for testosterone-induced BPH. In the cell line, LNCaP cells were exposed to *Q. indica* in combination with testosterone propionate (TP), and the levels of androgen receptor (AR) and prostate-specific antigen (PSA) were evaluated by western blot. In rats, daily injections of TP (3 mg per kg) were given for four weeks. Rows in the treatment group received *Q. indica* (150 mg per kg) administered simultaneously with topical painkillers. *In vitro* findings showed that *Q. indica* attenuated TP-induced increases in LNCI and PSA levels in the wild-type LNCI mutant (Wijerathne *et al.*, 2017). A comparative summary of the principal pharmacological investigations, including plant parts, experimental models, bioactive constituents, and major findings, is presented in **Table 2**.

Table 2. Summary of the reported pharmacological activities of *Quisqualis indica*, highlighting the plant part used, extraction solvent or formulation, major bioactive constituents, experimental model, dose or concentration, pharmacological activity, evidence level, and corresponding references.

Plant Part	Extraction Solvent/Formulation	Major Constituents	Experimental Model	Dose/Concentration	Pharmacological Activity	Evidence Level	Citation
Whole plant	Purified isolated compound	Kaempferol, 25-O-acetyl-23,24-dihydro-cucurbitacin F	CCRF-CEM leukemia cell line	NR	Inhibition of tumour cell proliferation and anticancer activity	*In vitro*	(Efferth *et al.*, 2008)
Leaves and twigs	Purified 25-O-acetyl-23,24-dihydro-cucurbitacin F	Cucurbitacin derivative	Human sarcoma cell lines (SW-872, SW-982, TE-671)	Dose-dependent treatment	Induced apoptosis and G2/M cell-cycle arrest	*In vitro*	(Birgit Lohberger *et al.*, 2015)
Flowers	Copper nanoparticles synthesized using flower extract	Polyphenol-mediated CuNPs	B16F10 melanoma cells and NIH3T3 fibroblasts	40–120 µg/mL (IC_{50} ≈102 µg/mL)	Dose-dependent cytotoxicity against melanoma cells with low toxicity toward normal fibroblasts	*In vitro*	(Mukhopadhyay *et al.*, 2018)
Seeds	70% ethanol extract	Quisqualic acid, trigonelline, rutin	LNCaP prostate cancer cells and testosterone-induced BPH rats	150 mg/kg (rats)	Reduced prostate enlargement; regulated AR and PSA expression	Combined preclinical (*In vitro* + *In vivo*)	(Wijerathne *et al.*, 2017)

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Flowers	Hydrodistilled floral extract	Quinoline-4-carbonitrile (QCN)	DPPH radical scavenging and anti-inflammatory assays	NR	Potent antioxidant and anti-inflammatory activity	*In vitro*	(Rout *et al.*, 2021)
Flowers	Water, ethanol and absolute ethanol extracts	Phenolics and flavonoids	DPPH, nitric oxide, hydroxyl radical scavenging assays	Up to 500 mg/L	Significant antioxidant activity; ethanol extracts showed superior activity	*In vitro*	(Afify & Hassan, 2016)
Leaves	Silver nanoparticles synthesized from leaf extract	AgNPs	*Aedes aegypti*, *Anopheles stephensi*, *Culex quinquefasciatus* larvae	LC_{50} = 12.52–14.63 µg/mL	Potent larvicidal activity for vector control	*In vivo*	(Govindarajan *et al.*, 2016)
Stem	Chloroform fraction of methanolic extract	Diphenylpropanoid derivatives	MRSA and MDR *Staphylococcus aureus* strains	MIC 128–256 µg/mL	Significant antibacterial activity	*In vitro*	(Jahan *et al.*, 2009)
Seeds	Plant extract (solvent NR)	Crude extract	Chickens infected with *Eimeria tenella*	NR	Reduced lesion scores, improved survival and weight gain	*In vivo*	(Youn & Noh, 2001)
Fruits	Crude plant extract	Rutin-containing extract	Pancreatic lipase assay	100 µg/mL	Pancreatic lipase inhibition indicating anti-obesity potential	*In vitro*	(Roh & Jung, 2012)

Abbreviations: AgNPs, silver nanoparticles; AR, androgen receptor; BPH, benign prostatic hyperplasia; CuNPs, copper nanoparticles; DPPH, 2,2-diphenyl-1-picrylhydrazyl; IC_{50}, half-maximal inhibitory concentration; LC_{50}, median lethal concentration; MIC, minimum inhibitory concentration; MDR, multidrug-resistant; MRSA, methicillin-resistant Staphylococcus aureus; NIH3T3, mouse embryonic fibroblast cell line; PSA, prostate-specific antigen; QCN, quinoline-4-carbonitrile; NR, not reported.

3.3. Antioxidant activity

Rout *et al.* (2021) isolated Quinoline-4-carbonitrile (QCN), a volatile alkaloid from the flower extract of *Q. indica*, which was found in different concentrations in live (5.7%) and harvested (1.3%) flowers, along with other major compounds such as (*E, E*)-α-farnesene, due to altered enzyme pathways during hydrodistillation. QCN, synthesised by the green chemistry process, and its derivative quinoline-4-carbonitrile, have been shown to have enhanced bio-activities, with the herbal extracts showing superior anti-inflammatory and antioxidant properties (19.7%) and synergistic effects, compared to essential oils containing only 1.1% QCN (Rout *et al.*, 2021).

Afify *et al.* (2016) evaluated the antioxidant activity of extracts of water, ethanol, and absolute ethanol from *Hibiscus rosa-sinensis*, *Q. indica*, and *Senna surattensis* flowers in a series of tests (DPPH scavenging, ferrous chelating, reducing power, nitric oxide scavenging, hydroxyl radical scavenging, and total antioxidant capacity). They found that *S. surattensis* had the highest total antioxidant capacity (0.479 ± 0.001 at 500 mg/L). All extracts had significant DPPH radical scavenging (up to 90.20 ± 0.29% at 500 mg/L), phytochemical screening detected various bioactive compounds, with *H. rosa-sinensis* showing the highest phenolic content in water extract (235.77 ± 14.31 mg/100 g). In contrast, *Q. indica* and S. surattensis showed higher phenolic content in ethanol extracts (937.70 ± 25.06 and 850.30 ± 13.81 mg/100 g, respectively). Absolute ethanol extracts contained the highest total flavonoids across all three flowers (32.83 ± 1.34, 49.24 ± 4.87, and 2.79 ± 0.23 mg/100 g, respectively) (Afify & Hassan, 2016).

3.4. Antimalarial activity

Govindarajan *et al.* (2016) investigated the biophysical characteristics and mosquito-killing potential of silver nanoparticles (AgNPs) synthesised using *Q. indica*. The nanoparticles were characterised using various spectroscopic and microscopic methods, confirming their spherical, polydispersed structure ranging from 1–30 nm in size, along with

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their crystalline nature. Toxicity assessments indicated that the *Q. indica* leaf extract exhibited moderate larvicidal activity against the disease vectors *Culex quinquefasciatus* (LC_{50} = 220.42 µg/mL), *Aedes aegypti* (LC_{50} = 203.63 µg/mL), and *Anopheles stephensi* (LC_{50} = 185.98 µg/mL). However, the AgNPs synthesised from *Q. indica* demonstrated significantly enhanced larvicidal efficacy, with much lower LC_{50} values (14.63, 13.55, and 12.52 µg/mL, respectively) against the same mosquito species. Furthermore, these nanoparticles showed only moderate toxicity towards non-target aquatic predators like *Anisops bouvieri*, *Diplonychus indicus*, and *Gambusia affinis* (LC_{50} values of 653.05, 860.94, and 2183.16 µg/mL, respectively). These findings highlight the potential of this low-cost, eco-friendly biogenic method for controlling vectors of Zika virus, malaria, and filariasis while minimising environmental harm (Govindarajan *et al.*, 2016).

3.5. Antibacterial activity

Jahan *et al.* (2009) isolated four diphenylpropanoid compounds, 1 - (4-hydroxy-3-methoxy phenyl) -2- (4-allyl-2,6-dimethoxy phenoxy) propan-1-ol, 1 - (3,4-dimethoxyphenyl) -2- (4-allyl - 2, 6-dimethoxy phenoxy) propan-1-yl acetate, 1-(3,4-dimethoxy phenyl)-2-(4-allyl-2,6-dimethoxy phenoxy) propan-1-ol, and 1-(4-hydroxy-3,5-dimethoxy phenyl) -2-(4-allyl-2,6-dimethoxy phenoxy) propan-1-ol were extracted from the chloroform-soluble portion of a methanolic extract of *Q. indica*. Their structures were clearly elucidated through mass spectrometry (MS) along with comprehensive one-dimensional (1D) and two-dimensional (2D) nuclear magnetic resonance (NMR) spectroscopy analyses. Their structure has been clearly elucidated by means of mass spectrometry (MS) and a complex analysis of one-dimensional (1D) and two-dimensional (2D) nuclear magnetic resonance spectra. All isolated compounds were assessed for their anti-staphylococcal activity against five strains of multi-drug resistant Staphylococcus aureus (MDR) and methicillin-resistant *Staphylococcus aureus* (MRSA) and showed minimal inhibitory concentrations (MICs) of 128 to 256 µg/mL (Jahan *et al.*, 2009).

Prashanth *et al.* (2006) extracted approximately 10 g powder from the product using dichloromethane and methanol (1:1, v and v) (2 x 50 ml) under reflux for 30 minutes and then filtration. The antibacterial and antifungal activity was assessed using a topical lubricant suspension. The extracts from the plant material were tested in dichloromethane at doses of 500 mg and 1000 mg/mL on food agar (NA) or on dextrose agar (SDA) in a centrifuge. Extractives were placed in the medium, diluted in a solvent, and seasoned. The bacterial and fungal inocula were then distributed to different sections of the agar plate, and incubated for a period of 37^0 Celsius for bacteria and 28^0 Celsius for fungi, before weighing (Kumar *et al.*, 2006).

3.6. Anticoccidial activity

Youn *et al.* (2001) assessed survival rates, lesion scores, weight gain, incidence of bloody diarrhoea, and oocystian secretion during the first and second weeks after awakening. The groups treated with *Sophora flavescens* and *Sinomenium acutum* had milder bloody diarrhoea than the other groups. Survival rates were particularly high in the groups treated with *Ulmus macrocarpa* (100%) and *Pulsatilla koreana*, *Torilis japonica*, *Artemisia asiatica,* and *S. flavescens* (90%). Symptoms were significantly reduced in groups treated with *U. macrocarpa* (1.40 ± 1.14) and P. koreana (1.60 ± 1.82) compared with the control group. In addition, weight gain during the first week after infection was significantly greater in the groups treated with *Q. indica*, *S. flavescens,* and *S. acutum* (Youn & Noh, 2001).

3.7. Anti-obesity activity

Roh *et al.* (2012) evaluated 44 crude extracts from wild plants at a dose of 100 mg per ml for their ability to inhibit the activity of pancreatic lipase (PLP) using a 2,4-dinitrophenylbutyrate assay. Four extracts had more than 30% activity against lipases: Rubi fruit (32.5), Cornus fruit (34.8), Salicylic acid cortex (38), and Geranium nepalense (31.4). Orlistat, a well-known anti-lipase drug, significantly reduced PPL activity at a final concentration of 100 mg/mL (Roh & Jung, 2012). The pharmacological effects of *Q. indica* involve multiple mechanisms, including modulation of oxidative stress, inflammatory signalling, apoptosis, cell-cycle progression, microbial growth, androgen signalling, and neuronal pathways. The reported mechanisms, experimental models, doses or concentrations, and levels of evidence are summarized in **Table 3.**

Table 3. Proposed pharmacological mechanisms of *Quisqualis indica* and its major bioactive compounds, including extraction solvent or formulation, experimental model, dose or concentration, mechanism of action, evidence level, and corresponding references.

Pharmacological Activity	Major Active Compounds / Extract	Extraction Solvent / Formulation	Experimental Model	Dose / Concentration	Proposed Mechanism	Evidence Level	Citation
Anticancer activity	25-O-acetyl-23,24-dihydro-cucurbitacin F, kaempferol	Purified isolated compound	Human sarcoma cell lines (SW-872, SW-982, TE-671) and CCRF-CEM leukemia cells	Dose-dependent treatment (exact concentration NR)	Induction of apoptosis, G2/M cell-cycle arrest, and inhibition of tumour cell proliferation	*In vitro*	(Efferth *et al.*, 2008; Birgit Lohberger *et al.*, 2015)

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Antioxidant activity	Polyphenols, flavonoids, quinoline-4-carbonitrile	Ethanol, aqueous, hydrodistilled floral extracts	DPPH, nitric oxide, hydroxyl radical scavenging and reducing power assays	Up to 500 mg/L (Afify *et al.*); NR for other studies	Scavenging of reactive oxygen species (ROS) and attenuation of oxidative stress	*In vitro*	(Afify & Hassan, 2016; Rout *et al.*, 2021)
Anti-inflammatory activity	Flavonoids and phenolic compounds	Ethanolic and floral extracts	*In vitro* biochemical assays	NR	Inhibition of pro-inflammatory mediators and inflammatory signaling pathways	*In vitro*	(Kumar & Pandey, 2013; Romano *et al.*, 2013)
Antibacterial activity	Diphenylpropanoid derivatives	Chloroform fraction of methanolic extract	MRSA and MDR *Staphylococcus aureus* strains	MIC 128–256 µg/mL	Disruption of bacterial cell integrity and inhibition of microbial growth	*In vitro*	(Jahan *et al.*, 2009)
Antimalarial / Larvicidal activity	Silver nanoparticles synthesized using leaf extract	Biogenic silver nanoparticle formulation	*Aedes aegypti*, *Anopheles stephensi*, *Culex quinquefasciatus* larvae	LC_{50} = 12.52–14.63 µg/mL	Larvicidal toxicity resulting in effective vector control	*In vivo*	(Govindarajan *et al.*, 2016)
Anti-obesity activity	Rutin-rich polyphenolic extract	Crude plant extract	Pancreatic lipase inhibition assay	100 µg/mL	Inhibition of pancreatic lipase and reduction of lipid absorption	*In vitro*	(Roh & Jung, 2012)
Anticoccidial activity	Crude seed extract	Plant extract (solvent NR)	Chickens infected with *Eimeria tenella*	NR	Suppression of parasite development and improvement of host immune response	*In vivo*	(Youn & Noh, 2001)
Neuropharmacological activity	Quisqualic acid	Ethanolic seed extract / isolated compound	Experimental neurological studies	NR	Activation of glutamate receptors and modulation of neuronal signaling pathways	Preclinical	(Rastogi R, 1990; Wijerathne *et al.*, 2017)
Benign prostatic hyperplasia (BPH)	Ethanolic seed extract containing trigonelline, rutin and quisqualic acid	70% ethanol seed extract	LNCaP prostate cancer cells and testosterone-induced BPH rat model	150 mg/kg (rats)	Downregulation of androgen receptor (AR) and prostate-specific antigen (PSA); inhibition of prostate cell proliferation and induction of apoptosis	Combined preclinical (*In vitro* + *In vivo*)	(Wijerathne *et al.*, 2017)

Abbreviations: AR, androgen receptor; BPH, benign prostatic hyperplasia; DPPH, 2,2-diphenyl-1-picrylhydrazyl; LC_{50}, median lethal concentration; MIC, minimum inhibitory concentration; MDR, multidrug-resistant; MRSA, methicillin-resistant Staphylococcus aureus; NR, not reported; PSA, prostate-specific antigen; ROS, reactive oxygen species.

4. Discussion

The present systematic review critically synthesizes the available evidence regarding the phytochemistry and pharmacological activities of *Quisqualis indica*. Although the collective findings support the therapeutic potential of the plant, the current evidence base is characterized by considerable methodological heterogeneity, which limits direct comparison across studies and complicates the translation of preclinical findings into clinical applications. The reviewed investigations differ substantially in plant parts examined, extraction procedures, phytochemical characterization, experimental models, biological endpoints, and analytical techniques. Therefore, the pharmacological effects attributed to *Q. indica* should be interpreted within the context of these methodological differences rather than being considered universally comparable.

One of the most significant sources of variation among studies is the extraction methodology. Different investigators employed aqueous, methanolic, ethanolic, hydroethanolic, chloroform, dichloromethane, and nanoparticle-assisted

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extraction approaches, each yielding distinct phytochemical profiles. Ethanolic and hydroethanolic extracts consistently demonstrated higher concentrations of phenolic compounds and flavonoids than aqueous extracts, which generally translated into superior antioxidant activity in DPPH, nitric oxide, and hydroxyl radical scavenging assays (Afify & Hassan, 2016; Rout *et al.*, 2021). In contrast, Jahan *et al.* isolated diphenylpropanoid derivatives using chloroform fractions of methanolic extracts, demonstrating potent antibacterial activity against methicillin-resistant *Staphylococcus aureus* (MRSA) with minimum inhibitory concentrations ranging from 128–256 µg/mL (Jahan *et al.*, 2009). Similarly, Mukhopadhyay *et al.* synthesized copper nanoparticles using flower extracts, reporting enhanced cytotoxicity against melanoma cells compared with crude extracts, suggesting that nanotechnology-based formulations may improve biological activity by increasing stability and cellular uptake (Mukhopadhyay *et al.*, 2018). These findings collectively indicate that extraction solvent and formulation strategy substantially influence phytochemical recovery and pharmacological efficacy. Consequently, comparisons among studies using different extraction protocols should be interpreted cautiously.

Variation in the plant parts investigated represents another important source of heterogeneity. Leaves were primarily examined for antioxidant and larvicidal activities because of their abundance of phenolics and volatile constituents (Govindarajan *et al.*, 2016; Rout *et al.*, 2021). Flower extracts exhibited particularly strong antioxidant and anti-inflammatory effects owing to their high concentrations of polyphenols and quinoline alkaloids (Afify & Hassan, 2016; Rout *et al.*, 2021), whereas seeds were predominantly investigated for benign prostatic hyperplasia and neuropharmacological activities due to the presence of quisqualic acid and trigonelline (Wijerathne *et al.*, 2017). Stem extracts yielded structurally unique diphenylpropanoid derivatives responsible for antibacterial activity (Jahan *et al.*, 2009). These observations suggest that pharmacological properties are organ-specific and closely associated with differential metabolite distribution throughout the plant. However, only a limited number of studies quantitatively compared phytochemical profiles among different plant organs using standardized analytical methods. Consequently, it remains difficult to identify the optimal plant part for specific therapeutic applications.

A critical evaluation of the pharmacological evidence also demonstrates considerable differences in experimental design. Anticancer investigations primarily relied on established human cancer cell lines, including CCRF-CEM leukemia, SW-872 and SW-982 sarcoma cells, TE-671 rhabdomyosarcoma cells, and B16F10 melanoma cells (Efferth *et al.*, 2008; Birgit Lohberger *et al.*, 2015; Mukhopadhyay *et al.*, 2018). These studies consistently reported induction of apoptosis, inhibition of tumour cell proliferation, and G2/M cell-cycle arrest following treatment with cucurbitacin derivatives or nanoparticle formulations. Nevertheless, experimental conditions differed substantially with respect to extract concentration, exposure duration, and measured endpoints, limiting quantitative comparison between studies. Furthermore, most investigations lacked mechanistic validation through transcriptomic, proteomic, or pathway-specific analyses, thereby restricting understanding of the molecular mechanisms responsible for the observed cytotoxic effects.

The antioxidant evidence should likewise be interpreted critically. Most studies employed chemical assays such as DPPH, reducing power, nitric oxide scavenging, hydroxyl radical scavenging, and total antioxidant capacity (Afify & Hassan, 2016; Rout *et al.*, 2021). While these assays provide valuable preliminary information regarding free radical scavenging ability, they do not necessarily predict antioxidant efficacy under physiological conditions. Only a few studies evaluated intracellular oxidative stress or antioxidant enzyme modulation in biological systems. Moreover, antioxidant capacity varied considerably depending on solvent polarity, extraction conditions, and phenolic content. For example, Afify *et al.* reported that ethanol extracts contained substantially higher phenolic concentrations than aqueous extracts, resulting in superior radical-scavenging activity (Afify & Hassan, 2016). Such findings emphasize that differences in extraction methodology rather than intrinsic biological variation may explain many discrepancies reported among studies.

The antibacterial and antiparasitic evidence is similarly influenced by methodological variability. Diphenylpropanoid derivatives isolated by Jahan *et al.* demonstrated significant activity against multidrug-resistant and methicillin-resistant *Staphylococcus aureus* strains (Jahan *et al.*, 2009). In contrast, Prashanth *et al.* evaluated crude solvent extracts against a broader spectrum of microorganisms but reported comparatively modest antimicrobial effects [(Kumar *et al.*, 2006). These differences probably reflect variation in phytochemical purity, extract composition, microbial strains, susceptibility testing methods, and extract concentrations rather than contradictory biological properties. Likewise, Govindarajan *et al.* demonstrated that silver nanoparticles synthesized from *Q. indica* leaf extract exhibited substantially greater larvicidal activity than crude extracts while maintaining relatively low toxicity toward non-target aquatic organisms (Govindarajan *et al.*, 2016). Although these findings highlight the promise of nanotechnology-assisted phytopharmaceuticals, the absence of standardized nanoparticle synthesis protocols and long-term environmental safety evaluations limits their immediate practical application.

Studies investigating anti-obesity, anticoccidial, and benign prostatic hyperplasia represent valuable additions to the pharmacological profile of *Q. indica*, but the available evidence remains comparatively limited. Roh and Jung evaluated forty-four medicinal plant extracts and identified *Q. indica* as a potential pancreatic lipase inhibitor; however, the plant was not the principal focus of the investigation, and detailed phytochemical characterization was lacking (Roh & Jung, 2012). Similarly, Youn and Noh reported improvements in lesion scores, survival, and weight gain in chickens infected with *Eimeria tenella*, but *Q. indica* was evaluated alongside several medicinal plants, making attribution of efficacy specifically to *Q. indica* more difficult (Youn & Noh, 2001). Conversely, Wijerathne *et al.* employed both cell-based and animal models to investigate benign prostatic hyperplasia, providing stronger mechanistic evidence through evaluation

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of androgen receptor and prostate-specific antigen expression (Wijerathne *et al.*, 2017). Compared with purely descriptive pharmacological studies, this integrated experimental design provides greater confidence regarding biological plausibility and therapeutic relevance.

An important limitation identified across the included studies is the generally moderate quality of the available evidence. Most investigations were limited to *in vitro* experiments or small animal studies, whereas clinical evidence in humans is currently absent. Sample sizes were frequently modest, randomization and blinding procedures were rarely reported, and standardized quality-control measures for plant authentication and extract characterization were inconsistently applied. Furthermore, quantitative phytochemical analyses using validated chromatographic techniques were not uniformly performed, making reproducibility challenging. Considerable variability also existed in extraction yield, dosage regimens, treatment duration, and outcome assessment. Consequently, although the overall evidence consistently suggests beneficial pharmacological activities, the strength of evidence supporting clinical translation remains limited.

Another important observation emerging from this review is that many biological activities are likely attributable to synergistic interactions among multiple phytochemicals rather than a single active constituent. Flavonoids, phenolic acids, alkaloids, cucurbitacin derivatives, tannins, glycosides, and fatty acids may collectively regulate oxidative stress, inflammatory signalling, apoptosis, microbial growth, and metabolic pathways. However, few studies systematically evaluated synergistic or antagonistic interactions among isolated compounds. Future investigations integrating metabolomics, network pharmacology, molecular docking, transcriptomics, and systems biology approaches would substantially improve understanding of the complex pharmacological mechanisms underlying *Q. indica*.

The present systematic review demonstrates that Quisqualis indica possesses considerable pharmacological potential; however, the overall quality of the available evidence remains moderate and is predominantly based on preclinical investigations. Most published studies have evaluated the biological activities of *Q. indica* using *in vitro* cell culture systems or experimental animal models, whereas well-designed human clinical studies are currently unavailable. Consequently, although the reported pharmacological effects are encouraging, the current evidence is insufficient to support definitive clinical recommendations or therapeutic applications in human.

The majority of investigations examining anticancer, antioxidant, antibacterial, anti-inflammatory, and antiparasitic activities employed *in vitro* experimental models to evaluate cytotoxicity, free radical scavenging, antimicrobial efficacy, and modulation of inflammatory pathways (Afify & Hassan, 2016; Efferth *et al.*, 2008; Jahan *et al.*, 2009; Birgit Lohberger *et al.*, 2015; Mukhopadhyay *et al.*, 2018; Rout *et al.*, 2021). These models provide valuable mechanistic insights and facilitate the preliminary screening of bioactive constituents; however, they cannot adequately replicate the complexity of human physiology or reliably predict clinical efficacy. Furthermore, substantial methodological heterogeneity exists among studies regarding plant parts, extraction solvents, phytochemical composition, extract concentrations, exposure duration, and biological endpoints, thereby limiting reproducibility and direct comparison of findings (Afify & Hassan, 2016; Kulshreshtha *et al.*, 2018; Rout *et al.*, 2021; Sharma *et al.*, 2024).

Compared with cell-based investigations, animal studies provide stronger biological evidence because they evaluate pharmacological responses in integrated physiological systems. Experimental studies investigating benign prostatic hyperplasia, larvicidal activity, anticoccidial effects, and metabolic regulation consistently demonstrated promising therapeutic outcomes and supported the biological relevance of *Q. indica* under physiological conditions (Govindarajan *et al.*, 2016; Kim *et al.*, 2020; Roh & Jung, 2012; Wijerathne *et al.*, 2017; Youn & Noh, 2001). Nevertheless, most animal studies involved relatively small sample sizes, variable dosage regimens, and inconsistent treatment durations. Moreover, essential methodological characteristics, including randomization, blinding, standardized phytochemical characterization, and risk-of-bias assessment, were seldom reported, thereby reducing confidence in the available evidence (Chigbu *et al.*, 2023; Gough *et al.*, 2012; Grant & Booth, 2009).

A major limitation identified throughout the literature is the complete absence of high-quality clinical evidence. To date, no randomized controlled clinical trials have established the efficacy, optimal dosage, long-term safety, pharmacokinetic characteristics, bioavailability, or herb–drug interaction profile of *Q. indica* preparations in human populations. Consequently, the promising pharmacological activities observed in experimental models cannot yet be translated into evidence-based clinical practice. These findings emphasize the urgent need for rigorously designed clinical investigations before therapeutic recommendations can be justified (Frost *et al.*, 2022; Grant & Booth, 2009; Page *et al.*, 2021; Tugwell & Tovey, 2021).

Another important source of variability is the lack of phytochemical standardization. Different investigators utilized diverse plant parts, extraction techniques, analytical methods, and formulations, including aqueous, ethanolic, methanolic, hydroethanolic, chloroform, dichloromethane, and nanoparticle-assisted extracts, each yielding distinct phytochemical profiles and pharmacological responses (Afify & Hassan, 2016; Jahan *et al.*, 2009; Kulshreshtha *et al.*, 2018; Birgit Lohberger *et al.*, 2015; Mukhopadhyay *et al.*, 2018; Rout *et al.*, 2021; Sharma *et al.*, 2024). Because biological activity is closely associated with chemical composition, such methodological heterogeneity substantially reduces reproducibility and complicates comparison among independent studies. Future investigations should therefore employ authenticated botanical materials, standardized extraction procedures, validated chromatographic fingerprinting (HPLC, LC–MS/MS, or GC–MS), quantitative phytochemical profiling, and comprehensive quality-control protocols to improve

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consistency and facilitate clinical translation (Bezerra *et al.*, 2020; Herzyk *et al.*, 2024; Kulshreshtha *et al.*, 2018; Verma & Rawat, 2025).

Overall, the available literature consistently supports the therapeutic promise of *Q. indica*, particularly for its antioxidant, anticancer, antimicrobial, anti-inflammatory, antiparasitic, and metabolic regulatory activities. However, according to the current hierarchy of scientific evidence, the available data should be regarded as predominantly preclinical, with the strongest support arising from mechanistic *in vitro* studies and experimental animal models, while clinical evidence remains absent. Future research should therefore prioritize standardized phytochemical characterization, pharmacokinetic and toxicological investigations, multicenter animal studies, adherence to rigorous reporting standards, and well-designed randomized controlled clinical trials to establish the efficacy, safety, and translational potential of *Q. indica* as an evidence-based phytopharmaceutical agent.

5. Conclusion

Q. indica is a medicinal plant with a diverse phytochemical profile and promising pharmacological properties demonstrated in experimental studies. The available evidence indicates that its bioactive constituents possess antioxidant, anti-inflammatory, antimicrobial, anticancer, antiparasitic, and metabolic regulatory activities. However, these findings are derived predominantly from *in vitro* investigations and animal models, with little or no high-quality clinical evidence currently available to support therapeutic use in humans. Consequently, the existing data should be interpreted as evidence of preclinical potential rather than confirmed clinical efficacy. Despite encouraging experimental findings, several critical challenges limit the clinical translation of *Q. indica*. These include the lack of standardized extraction procedures and phytochemical characterization, variability in plant material and experimental methodologies, insufficient pharmacokinetic and bioavailability data, limited comprehensive toxicity and safety evaluations, and the absence of well-designed randomized clinical trials. Addressing these limitations is essential for establishing the efficacy, safety, and reproducibility of *Q. indica*-based therapeutic interventions. Future research should therefore prioritize the development of standardized extracts with validated phytochemical fingerprints, comprehensive pharmacokinetic and toxicological investigations, elucidation of molecular mechanisms of action using advanced omics and systems pharmacology approaches, optimization of formulation strategies to enhance bioavailability, and rigorous multicenter preclinical studies followed by adequately powered randomized clinical trials. Integrating these approaches will strengthen the evidence base and facilitate the rational development of *Q. indica* as a scientifically validated phytopharmaceutical. Overall, while *Q. indica* represents a valuable source of bioactive natural products, its successful translation into clinical practice will depend on robust, standardized, and evidence-based research that bridges the gap between promising laboratory findings and proven therapeutic applications.

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Ethical considerations
Not applicable

Conflict of Interest
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