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REVIEW ARTICLE

Nutritional, phytochemical and pharmacological attributes of seven *Ficus* species: current evidence and future prospects

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Abstract

Ficus fruits represent a promising yet underexplored group of edible medicinal resources within the Moraceae family. Key findings include, *Ficus assamica* and *F. hispida* exhibit exceptionally high phenolic and flavonoid concentrations; *F. semicordata* demonstrates a superior mineral profile; *F. racemosa* and *F. auriculata* show promising antidiabetic potential and *F. fistulosa* extract has already been tested clinically in a topical hydrogel that significantly reduced facial sebum without irritation. The most advanced pharmacological lead comes from *F. simplicissima*, whose coumarin compound bergapten, formulated as liposomes (Ber-lipo), has shown protective effects against lipopolysaccharide (LPS)-induced acute lung injury through modulation of macrophage activity and inflammatory signaling pathways. Despite these promising findings, research on *Ficus* fruits remains fragmented. Many studies lack standardised extraction methods, detailed sampling metadata or quantitative analysis of individual bioactive compounds. Toxicological data, pharmacokinetic profiles and controlled clinical trials are almost absent. To bridge these gaps, future research should prioritise standardised methodologies, comprehensive metabolomic profiling, safety and contaminant analyses and well-designed human studies to validate efficacy. With these advancements, *Ficus* fruits hold significant potential as nutraceutical and therapeutic resources for metabolic, inflammatory and respiratory health.

Keywords: Bangladesh; *Ficus* fruits; medicinal plants; nutraceuticals; pharmacology; phytochemicals

Introduction

The genus *Ficus* (Moraceae) comprises over 800 species worldwide, many of which produce edible fruits valued in traditional medicine and nutrition (1). Across diverse cultures, including Ayurveda, Chinese and indigenous medicinal systems, figs have been used to treat ailments such as digestive disorders, respiratory diseases, diabetes and skin infections. Beyond their cultural and therapeutic heritage, *Ficus* fruits offer a rich source of carbohydrates, proteins, fibers, vitamins and essential minerals, along with diverse secondary metabolites such as phenolics, flavonoids, tannins and coumarins (2, 3). These phytochemicals are largely responsible for the biological properties attributed to the genus, including antioxidant, anti-inflammatory, antimicrobial and antidiabetic effects (4, 5).

Despite these promising attributes, comprehensive and comparative analyses of fruit-based nutritional, phytochemical and pharmacological profiles across multiple *Ficus* species are limited. Factors such as geographical variation, environmental conditions and post-harvest processing contribute to the inconsistency in bioactive content and biological efficacy (6, 7). Consequently, systematic evaluation of different *Ficus* fruits under similar ecological conditions is crucial to establish reliable baselines for nutraceutical and pharmaceutical exploration.

This review focuses on 7 selected species: *Ficus assamica*, *F. auriculata*, *F. fistulosa*, *F. hispida*, *F. racemosa, F. semicordata* and *F. simplicissima*, whose fruit-bearing plants are all cultivated and maintained in the Bangladesh Agricultural University (BAU) Botanical Garden, Mymensingh. Their accessibility under uniform environmental conditions enables standardised comparative studies, making them ideal models for future nutritional, phytochemical and pharmacological investigations. Moreover, these species have shown significant traditional and experimental relevance, providing a strong basis for developing functional foods and plant-based therapeutics. This review exclusively focuses on *Ficus* fruits rather than other plant parts such as leaves, bark or latex. This decision was based on several scientific and practical considerations. First, the fruits are the most commonly consumed and culturally accepted part of the plant, often utilised as food and in traditional remedies. Second, harvesting fruits is non-destructive, promoting sustainable use and conservation of *Ficus* species, whereas extracting bark or roots can lead to long-term ecological damage. Third, *Ficus* fruits are rich in essential nutrients and bioactive compounds such as phenolics, flavonoids, tannins and coumarins, yet they remain underexplored compared to other parts of the plant. Lastly, existing literature predominantly emphasises leaves and bark; thus, focusing on fruits helps fill a significant research gap and facilitates the identification of safe, edible and sustainable therapeutic resources.

By consolidating current findings on their fruit composition and biological potential, this review aims to identify key research trends, reveal existing knowledge gaps and highlight future research priorities essential for the scientific validation and sustainable utilisation of *Ficus* biodiversity in Bangladesh and beyond (Fig. 1).

Literature Search Strategy and Selection Criteria

A comprehensive literature search was conducted to gather relevant information on the nutritional composition, phytochemical constituents and pharmacological properties of fruits from 7 *Ficus* species: *Ficus assamica*, *F. auriculata*, *F. hispida*, *F. fistulosa*, *F. racemosa*, *F. semicordata* and *F. simplicissima*. Major scientific databases, including PubMed, Scopus, ScienceDirect and Google Scholar, were utilised. Search terms combined each species name with keywords such as "fruit," "phytochemical," "nutritional composition," "bioactive compound," "antioxidant," "antimicrobial," "anti-inflammatory," "antidiabetic" and "traditional use." The search included studies published up to August 2025, as data collection and manuscript preparation were completed in August 2025 and prioritised peer-reviewed English-language articles.

Inclusion and exclusion criteria

Studies were included if they provided experimental or quantitative data specifically on the fruits of the selected *Ficus* species, including information on their nutritional composition, phytochemical content or pharmacological activities. Only studies that confirmed botanical identification or cited a voucher specimen were considered. In contrast, studies focusing solely on non-fruit parts such as leaves, bark, latex or roots, lacking analytical or experimental details, or that were not peer-reviewed (e.g., anecdotal or ethnobotanical-only sources) were excluded. Discrepancies among studies were handled in this review by contextual evaluation rather than numerical pooling, with greater weight given to results supported by comparable plant parts, extraction protocols and assay designs and reproduced across independent reports.

Data extraction and synthesis

Data from eligible studies were systematically collected and categorised into three main groups: (i) nutritional composition, covering proximate analyses such as moisture, ash, fat, fiber, protein, carbohydrate, energy and mineral or vitamin content; (ii) phytochemical constituents, including total phenolic (TPC) and

Fig. 1. Fruits of A. *Ficus assamica*; B. *Ficus hispida*; C. *Ficus auriculata*; D. *Ficus fistulosa*; E. *Ficus racemosa*; F. *Ficus semicordata* and G. *Ficus simplicissima.*

flavonoid (TFC) contents and major secondary metabolites such as alkaloids, coumarins and sterols; and (iii) pharmacological activities, comprising antioxidant, anti-inflammatory, antidiabetic, antimicrobial, analgesic, antiulcer and dermatological properties. When multiple reports were available for a single species, their findings were compared to identify consistent trends and notable variations and representative values were used when mean data were not provided.

Nutritional composition of *Ficus* fruits

Carbohydrates and energy content

Carbohydrates constitute the main component of *Ficus* fruits and serve as their primary energy source. *Ficus auriculata* fruits contain 10.9–35.42 % carbohydrates, providing 135–142 kcal/100 g (7–9). *Ficus hispida* and *F. fistulosa* exhibit 43.86 and 35.66 % carbohydrate content respectively (8), while *F. semicordata* contains 19.51g/100 g (10, 11). Drying methods, such as microwave treatment, help preserve carbohydrate levels, maintaining around 27 % in *F. auriculata* (5). Overall, carbohydrates are the dominant nutrient across the studied *Ficus* species, supporting their energy contribution and nutritional significance.

Proteins

Protein content in *Ficus* fruits varies moderately among species but contributes significantly to their nutritional value. *Ficus auriculata* contains 3.19 ± 1.0 % (8) to 5.32 ± 0.04 % (9) crude protein, while *F. hispida* and *F. fistulosa* exhibit 3.11 ± 1.0 and 2.90 ± 1.0 % respectively (8). *Ficus semicordata* fruits showed higher protein levels, 5.18 % (12) and up to 9.78 g/100 g (10, 11), indicating superior nutritional potential among the studied species.

Lipids and fats

All *Ficus* fruits are characteristically low in fat, which enhances their dietary suitability. *Ficus auriculata* fruits contain 0.01 ± 0 to 0.65 ± 0.25 % lipid (8, 9), while *F. fistulosa* shows only 0.02 ± 0 % lipid. *Ficus hispida* contains 1.08 g fat/100 g, while *F. semicordata* contains 1.00 % fat (12, 13). These values suggest that *Ficus* fruits are naturally low-fat foods with minimal caloric burden.

Fiber content

Dietary fiber, an essential component for digestive health, is present in appreciable amounts. *Ficus auriculata* has 1.82 ± 1.0 to 16.96 ± 0.09 % fiber, (8, 9), while 2.14 % fiber is present in *F. hispida* (7) and *F. fistulosa* contains 1.71 ± 1.0 and 1.61 ± 1.0 %, respectively (8). In comparison, *F. semicordata* showed higher values (15.5 % fiber) (12), emphasising its potential as a high-fiber dietary source.

Mineral composition

Several *Ficus* species are rich in essential minerals that support human health. In *F. auriculata*, calcium, magnesium, potassium and phosphorus were reported at 1.35, 0.90, 2.11 and 0.28 mg/100 g, respectively (9). *Ficus hispida* fruits contained iron (315 ppm), calcium (7.62 mg/100 g) and phosphorus (1312 mg/100 g) (13). *Ficus semicordata* was particularly mineral-rich, showing iron (264.62 ppm), zinc (10.24 ppm), manganese (11.36 ppm), phosphorus (0.17 ppm) and calcium (2623.09 ppm) (10, 11). These findings confirm that *F. semicordata* and *F. hispida* are among the most mineral-dense species within the genus.

Bioactive and phytochemical constituents

Beyond basic nutrition, *Ficus* fruits contain a variety of bioactive compounds with medicinal significance. *Ficus auriculata* fruits contain about 10 mg vitamin C per 100 g (7), while *F. assamica* extracts are notably rich in total phenolics (120 ± 3.14 mg GAE (Gallic acid equivalent) g^{-1}) and flavonoids (428.33 ± 7.07 mg QE (Quercetin equivalent) g^{-1}) (14). These compounds contribute to the fruits' antioxidant and therapeutic properties, making them valuable in both traditional medicine and functional food development. Although detailed proximate data for *F. simplicissima* are limited, the species is widely recognised for its ethnomedicinal relevance (Table 1) (14).

These results demonstrate that *Ficus* fruits are generally low in fat but rich in carbohydrates, protein, fiber and minerals. *Ficus auriculata* and *F. racemosa* offer a balanced nutrient composition suitable for dietary applications, while *F. semicordata* stands out for its mineral density. The diversity among species underscores the potential of *Ficus* fruits as sustainable, underutilised food resources with significant nutritional and nutraceutical importance.

Phytochemical profiles and bioactive compounds of *Ficus* fruits

Ficus fruits are rich sources of bioactive secondary metabolites, including phenolics, flavonoids, tannins, coumarins, terpenoids and phytosterols, which contribute to their antioxidant, antimicrobial, antidiabetic, anti-inflammatory, anticancer, neuropharmacological and cosmeceutical properties.

Total phenolic and flavonoid content

Phenolic compounds are key contributors to the antioxidant potential of *Ficus* fruits. *Ficus assamica* fruit extract contains 120 ± 3.14 mg GAE g^{-1} extract (TPC) and 428.33 ± 7.07 mg QE g^{-1}

Table 1. Mean nutritional composition of selected *Ficus* fruits (per 100 g edible portion)

Species	Carbohydrate (%)	Protein (%)	Fat (%)	Fiber (%)	Energy (kcal)	Moisture (%)	Notable minerals (ppm)	References
Ficus assamica	-	-	-	-	-	-	-	
Ficus auriculata	30.76 ± 9.4	4.26 ± 1.1	0.33 ± 0.3	9.39 ± 8.0	138.6 ± 3.1	58.2 ± 15.9	Ca 13.5, Mg 9.0, K 21.1, P 2.8	(5, 7, 9)
Ficus fistulosa	35.66 ± 4.4	2.90 ± 1.0	0.02 ± 0.00	1.61 ± 1.0	142.3 ± 23.4	44.0 ± 5.3	-	(6, 15)
Ficus hispida	43.86 ± 5.3	3.11 ± 1.0	0.00	1.71 ± 1.0	175.4 ± 28.1	36.3 ± 5.6	Fe 31.5, Ca 7.62, P 132;	(16–18)
Ficus racemosa	18.08 ± 10.1	3.32 ± 2.6	1.04 ± 0.04	8.02 ± 7.1	138.9 ± 0.3	62.9 ± 24.7	-	(12, 19, 20)
Ficus semicordata	19.51 ± 0.3	9.78 ± 2.3	2.96 ± 0.2	15.5 ± 0.5	138.9 ± 0.1	-	Fe 264.62, Zn 0.24, Mg 11.36, P 0.17, Ca 2623.09	(11, 14, 21)
Ficus simplicissima	-	-	-	-	-	-	-	

(- indicates data not reported in the literature).

extract (TFC), indicating strong antioxidant potential (22). *Ficus fistulosa* fruits and leaves showed exceptionally high phenolic content, especially in remote forest samples, with TPC of 452.25 mg GA/100 g, ferric reducing antioxidant power (FRAP) of 321.75 mg TE (Trolox equivalent)/100 g, 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity of 90.54 % and oxygen radical absorbance capacity (ORAC) of 158.36 μ mol TE g^{-1} (6). *Ficus racemosa* fruit extracts optimised at 40 % ethanol, 42.5 °C for 80 min yielded TPC of 80.10 ± 2.51 mg GAE g^{-1} and TFC of 79.31 ± 5.11 mg RE (Rutin equivalent) g^{-1}, with DPPH radical scavenging of 51.20 ± 3.21 % (23).

Ficus simplicissima (*F. hirta*) fruits and roots also exhibit notable phenolic and flavonoid contents, with acetone extracts showing TPC 85.25 ± 1.72 mg GAE g^{-1} (dw) and TFC 144.22 ± 8.46 mg RE g^{-1} (dw). These compounds are primarily flavonoid glycosides (luteolin-, apigenin-, naringenin- and eriodictyol-7-O-glucosides), coumarins (umbelliferone) and benzoylquinic acid derivatives, which correlate with strong antioxidant and antifungal activities (24). Moreover, purified phenylpropanoids from *F. hirta* roots showed marked inhibition of LPS-induced nitric oxide production in macrophage RAW 264.7 cells, confirming pronounced anti-inflammatory effects (25). *Ficus auriculata* fruits also demonstrate high phenolic levels, contributing to their antioxidant capacity (26). *Ficus hispida* fruits are particularly rich in phenolics and flavonoids, with the crude methanolic extract (CME) showing TPC 286 ± 1.63 mg GAEs g^{-1} extract and TFC 181.67 ± 3.11 mg CEs (Catechin equivalents) g^{-1} extract. Various solvent fractions retain significant phenolic and flavonoid contents, including ethyl acetate fraction (TPC 210.50 ± 1.87 mg GAEs g^{-1}; TFC 29.17 ± 3.11 mg CEs g^{-1}) and aqueous fraction (TPC 244.33 ± 1.31 mg GAEs g^{-1}; TFC 129.17 ± 3.11 mg CEs g^{-1}), correlating with strong antioxidant and free-radical scavenging activity (18, 27). These variations reflect both species-specific traits and environmental influences, including forest locality and extraction conditions.

Tannins and astringent activity

Tannins, which are polyphenolic compounds, are responsible for the astringent taste of several *Ficus* fruits and contribute to dermatological applications. *Ficus fistulosa* fruit extract contains 0.0359 ± 0.0003 mg tannic acid equivalent per gram, with astringent activity of 87.45 ± 1.76 %. This extract effectively reduced sebum content by 54.36 ± 13.71 % in volunteers over 28 days, supporting its potential in cosmeceutical formulations (15). *Ficus simplicissima* also exhibits sebum-regulating potential, attributed to its phenolic and coumarin-rich profile and strong antioxidant activity, indicating usefulness in hydrogel or dermatological preparations (24). *Ficus hispida* contains tannins contributing to antioxidant, analgesic and anti-inflammatory effects, supporting its traditional dermatological and wound-healing uses (28, 29).

Bioactive compounds and phytosterols

Several *Ficus* fruits contain unique bioactive molecules that underpin their pharmacological activities. *Ficus racemosa* fruits harbor glucosides, flavonoids, tannins, saponins, terpenoids and phytosterols such as β-sitosterol, glauanol, glauanol acetate and lupeol acetate (19, 30). *Ficus simplicissima* roots yield four new phenylpropanoids (compounds 1–4) and ten known phenolics, including luteolin, apigenin, naringenin, eriodictyol glycosides, umbelliferone and benzoylquinic acids (25). These compounds exhibit pronounced inhibition of LPS-induced nitric oxide production in macrophage RAW 264.7 cells, surpassing indomethacin, confirming potent anti-inflammatory potential. In addition, coumarin derivatives such as bergapten isolated from *F. simplicissima* have been developed into a lung-targeted nanomedicine (Ber-lipo) showing therapeutic efficacy against acute lung injury through modulation of macrophage activity and the TLR4/MyD88/NF-κB pathway (4). *Ficus auriculata* fruits provide isoflavones, including (Z)-5,7,4′-trihydroxy-3′-[3-hydroxy-3-methyl-1-butenyl] isoflavone and seven known analogues with potent antibacterial activity (31, 32). Overall, the chemical richness of *F. racemosa* supports its prioritisation for bioactivity and preclinical investigation as a source of anti-inflammatory and antimicrobial leads (33). *Ficus hispida* fruits contain diverse constituents: isoflavones, coumarins, caffeoylquinic acids, phenolics, steroid glucosides and alkaloids; demonstrating anticancer, chemopreventive, antioxidant, analgesic, sedative, hepatoprotective and neuropharmacological effects, supporting their traditional use for skin, respiratory, urinary and pain disorders (Table 2).

Pharmacological activities of *Ficus* fruits

Ficus fruits exhibit a broad spectrum of pharmacological properties due to their rich phytochemical content, making them valuable for traditional medicine, nutraceuticals and emerging therapeutic applications.

Antioxidant activity

Ficus fruits consistently show strong antioxidant potential, supporting their use in oxidative stress-related disorders. *Ficus semicordata* fruits demonstrated dose-dependent antioxidant activity across DPPH, FRAP and phosphomolybdenum assays, linked to their tannin and alkaloid content (10). *Ficus assamica* fruit extract (TPC 120 mg GAE g^{-1}, TFC 428.33 mg QE g^{-1}) revealed potent antioxidant activity, highlighting its ability to scavenge free radicals and reduce oxidative damage (22). *Ficus fistulosa* extracts showed FRAP values 278.43–321.75 mg TE/100 g, DPPH inhibition 80.71–90.54 % and ORAC 121.66–158.36 μmol TE g^{-1}, reflecting species- and environment-dependent antioxidant potential (6). *Ficus racemosa* fruit extract displayed improved antioxidant capacity after *Aspergillus niger* solid-state fermentation (F-FRFE), which protected human hepatocytes from H_2O_2-induced apoptosis and alleviated oxidative stress in diabetic mice (20). *Ficus simplicissima* (syn. *F. hirta*) fruit extracts exhibited strong antioxidant activity, with acetone extract showing TPC 85.25 ± 1.72 mg GAE g^{-1} dw and TFC 144.22 ± 8.46 mg RE g^{-1} dw and the lowest IC_{50} = 2.02 mg mL^{-1} in DPPH radical-scavenging assay. These results correlated positively with phenolic and flavonoid levels (R^2 = 0.82-0.92), indicating that medium-polarity solvents such as acetone and ethyl acetate are optimal for recovering antioxidant constituents (24). *Ficus hispida* fruit extracts and fractions, particularly the crude methanolic extract (TPC 286 mg GAEs g^{-1}, TFC 181.67 mg CEs g^{-1}), demonstrated strong DPPH radical scavenging activity (IC_{50} ≈ 11.2 μg mL^{-1}), hydrogen peroxide scavenging and concentration-dependent total antioxidant capacity, attributed to isoflavones, coumarins, caffeoylquinic acids, phenolics and steroid glucosides (17, 18).

Overall, *Ficus hispida* appears to be the most potent antioxidant species among the reviewed fruits, followed by *F. simplicissima* and *F. fistulosa*, with activity closely linked to phenolic and flavonoid richness.

Anti-inflammatory activity

Several *Ficus* fruit extracts inhibit inflammatory pathways, protein denaturation and sebum overproduction. *Ficus simplicissima* roots yielded four new phenylpropanoids and ten known phenolics, some of which exhibited strong inhibition of LPS-induced nitric oxide (NO)

Table 2. Summary of major phytochemicals

Species	Major phytochemicals / bioactive compounds	Total phenolic content (TPC)	Total flavonoid content (TFC)	Key bioactivity	References
Ficus assamica	Phenolics, flavonoids	120 ± 3.14 mg GAE g^{-1}	428.33 ± 7.07 mg QE g^{-1}	Strong antioxidant and anti-inflammatory (protein denaturation inhibition)	(14, 22)
Ficus auriculata	Isoflavones, phenolic acids (gallic, caffeic), rutin, flavonoids	124.6 mg GAE g^{-1}	76.4 mg QE g^{-1}	Antioxidant, antimicrobial, α-amylase/ α-glucosidase inhibition	(5, 26, 31, 32, 34, 35)
Ficus fistulosa	Tannins, polyphenols	452.25 mg GA/100 g (leaves/fruits)	-	Potent antioxidant; sebum reduction in topical cosmetic hydrogel	(6, 15)
Ficus hispida	Isoflavones, coumarins, caffeoylquinic acids, phenolics, steroid glucosides, flavonoids, tannins, saponins, alkaloids	CME: 286 ± 1.63 mg GAE g^{-1}; NHF: 35.66 ± 0.62; CHF: 185.66 ± 5.54; EAF: 210.50 ± 1.87; AQF: 244.33 ± 1.31	CME: 181.67 ± 3.11 mg CE g^{-1}; CHF: 100.00 ± 2.04; AQF: 129.17 ± 3.11	Anti-inflammatory, antioxidant, wound healing, moderate antidiabetic	(8, 14, 16, 27, 36)
Ficus racemosa	Flavonoids, tannins, terpenoids, phytosterols, β-sitosterol, lupeol acetate	80.10 ± 2.51 mg GAE g^{-1}	79.31 ± 5.11 mg RE g^{-1}	Antioxidant, antimicrobial, antidiabetic	(12, 19, 20, 37)
Ficus semicordata	Tannins, alkaloids, phenolics	-	-	Antioxidant, antidiabetic, antibacterial	(11, 14, 21)
Ficus simplicissima	Bergapten(coumarin), phenolics, flavonoids, coumarins (luteolin, apigenin, naringenin, eriodictyol glycosides, umbelliferone)	85.25 ± 1.72 mg GAE g^{-1} (dw)	144.22 ± 8.46 mg RE g^{-1} (dw)	Anti-inflammatory; lung-targeted therapy (acute lung injury)	(4, 14)

(CME = Crude methanolic extract; NHF = n-Hexane fraction; CHF = Chloroform fraction; EAF = Ethyl acetate fraction; AQF = Aqueous fraction).

production in RAW 264.7 macrophages, comparable to indomethacin, confirming its potential as a natural anti-inflammatory agent (25). The fruit extracts also show topical anti-inflammatory properties: An acetone extract-based hydrogel reduced sebum content by 54.36 ± 13.71 % without irritation, reflecting both antioxidant and astringent effects (24). *Ficus hispida* fruits and leaves have also been reported to suppress inflammatory mediators and oxidative stress, supporting their traditional use in skin disorders, respiratory ailments and wound healing (28).

Among the studied species, *F. simplicissima* shows the strongest anti-inflammatory potential, supported by both cellular inhibition of inflammatory mediators and topical efficacy.

Antidiabetic activity

Insulin-mimetic or insulin-releasing mechanisms mediate hypoglycemic effects of *Ficus* fruits. *Ficus racemosa* fruit extracts reduced blood glucose levels in type 1 diabetic rats and alloxan-induced diabetic rabbits. Methanolic extracts lowered glucose by 31.2 % *in vivo*, while β-sitosterol exhibited potent hypoglycemic activity. Fermented fruit extract (F-FRFE) completely suppressed hyperglycemia in diabetic mice (12, 20, 33). *Ficus semicordata* fruits also showed antidiabetic potential, likely linked to tannin and alkaloid content (21). *Ficus hispida* exhibits moderate antidiabetic activity, consistent with its traditional use in managing hyperglycemia and supporting further pharmacological evaluation.

Comparative evidence indicates that *F. racemosa* exhibits the most pronounced antidiabetic activity among *Ficus* fruits, particularly in experimental models of hyperglycemia.

Antimicrobial activity

Ficus fruits exhibit antibacterial and antifungal activities, particularly against wound pathogens. *Ficus racemosa* methanolic fruit extract was effective against *Staphylococcus aureus*, *Bacillus cereus*, *Klebsiella pneumoniae* and *Escherichia coli*, with inhibition zones up to 26 mm. The minimum inhibitory concentration (MIC) for *Staphylococcus* spp. was 0.07 mg mL^{-1} (12, 34). *Ficus auriculata* fruit extracts inhibited *Shigella flexneri*, *E. coli* and *Staphylococcus epidermidis*, showing broad-spectrum antimicrobial effects (9, 26). *Ficus simplicissima* extracts also showed broad-spectrum antifungal activity, producing inhibition zones of 27.5–41.75 mm against *Penicillium italicum*, *P. digitatum*, *A. niger*, *A. oryzae*, *Saccharomyces cerevisiae* and *Candida utilis*, comparable to or exceeding natamycin (24). This activity correlates with high flavonoid levels and the presence of phenylpropanoid and coumarin derivatives.

Among the evaluated species, *F. simplicissima* demonstrates the broadest and most effective antimicrobial spectrum, especially against fungal pathogens.

Antiulcer and gastroprotective effects

Ficus fruit extracts mitigate gastric ulceration in experimental models. *Ficus racemosa* 50 % ethanol fruit extract significantly reduced ulcer index in pylorus ligation, ethanol and cold restraint stress-induced ulcers in rats, indicating dose-dependent gastroprotective activity (30). *Ficus hispida* has also been traditionally used to treat gastrointestinal disorders, though systematic *in vivo* studies are limited.

Analgesic and antinociceptive effects

Fruit extracts demonstrate pain-modulating properties. *Ficus racemosa* ethanolic fruit extract at 500 mg kg^{-1} produced 61.38 % inhibition in acetic acid-induced writhing in mice, significantly higher than the bark extract (42.6 %), confirming potent antinociceptive activity (38). *Ficus hispida* ethanolic fruit extract exhibited dose-dependent antinociceptive effects in acetic acid-induced writhing tests, with up to 62.84 % inhibition at 500 mg kg^{-1}, supporting its use in traditional medicine for pain relief (16, 29).

Cosmeceutical applications

The astringent, antioxidant and anti-inflammatory properties of *F.* fruits offer potential in skincare formulations. *Ficus fistulosa* hydrogel containing 0.1 % fruit extract reduced sebum secretion by 54.36 % without irritation, illustrating its potential in managing seborrhea and enlarged pores (15). *Ficus simplicissima* fruit extracts showed similar sebum-regulating and antioxidant effects, suggesting potential in antioxidant hydrogels and anti-sebum skincare formulations (24). *Ficus hispida*, rich in phenolics, flavonoids, isoflavones and coumarins, may also support dermatological applications and wound healing, though formulation studies are limited. Among *Ficus* fruits explored for skincare applications, *F. fistulosa* emerges as the most promising candidate for sebum control and cosmetic formulations (Table 3).

Current status and future perspectives

Across the 7 *Ficus* species reviewed, the most pressing, cross-cutting deficiencies are consistent: lack of standardised sample handling and reporting, limited compound-level identification, sparse safety/toxicology and contaminant data and almost no human clinical evidence. These gaps prevent reproducible comparison between studies, block regulatory pathways and hinder responsible translation from promising preclinical signals to consumer products or therapeutics (5, 8, 11). The highest immediate priority, therefore, is to establish harmonised quality and reporting metrics and basic safety screens across species; doing so is necessary to validate bioactivity claims, enable interlaboratory replication and create a foundation for subsequent mechanistic and clinical research.

Ficus assamica presents high total phenolic and flavonoid levels (TPC 120 ± 3.14 mg GAE g^{-1}; TFC 428.33 ± 7.07 mg QE g^{-1}) and robust, dose-dependent inhibition of heat-induced protein denaturation, indicating strong anti-inflammatory potential (14, 22). What is missing are the identities and concentrations of the specific phenolic/flavonoid molecules responsible, mechanistic data linking those molecules to inflammatory pathways and any safety/toxicology information. The highest-priority research task is therefore to isolate and chemically characterise the dominant bioactive phenolics and obtain foundational safety profiles. This is necessary to enable standardised extracts, reproducible bioassays and responsible progression toward topical or oral nutraceutical applications (22).

Ficus hispida is chemically rich, with numerous compounds, including two new isoflavones, isolated and its extracts show high phenolic and flavonoid content along with antioxidant, cytotoxic, antinociceptive and neuropharmacological activities (16–18, 27, 29). However, quantitative standardisation across collections, mechanistic validation of the most promising isoflavones and phenolics and systematic safety/ADME (absorption, distribution, metabolism and excretion) information are lacking. The top priority is therefore quantitative prioritisation of the major isolated compounds (i.e., reproducible profiling and selection of leads) followed by targeted safety de-risking. This focus is necessary to distinguish therapeutic candidates with acceptable selectivity and safety from cytotoxic constituents unsuitable for further development.

Ficus auriculata is among the best characterised species in this set: high-performance liquid chromatography (HPLC) and liquid chromatography-mass spectrometry (LC-MS) data identify gallic and caffeic acids, rutin and isoflavones and several studies report strong enzyme-inhibitory (α-amylase and α-glucosidase) and antimicrobial activities (5, 9, 26, 31, 35). The remaining gaps include harmonisation of processing and extraction methods to allow direct comparisons, ADME and toxicity data for the active fractions or isolated isoflavones and controlled human efficacy data for antidiabetic claims. Priority should be placed on confirming safety and pharmacokinetic permissibility for the lead antidiabetic fractions so that small, well-controlled human postprandial studies may follow. Securing these data is essential to translate promising enzyme inhibition into validated nutraceutical or adjunct therapeutic use.

Ficus fistulosa combines high phenolic load and potent antioxidant capacity with an already demonstrated human cosmetic effect: A 0.1 % hydrogel produced a mean sebum reduction of ≈ 54 % with no irritation in a pilot study (6, 15). The main lacunae are larger, controlled clinical trials, chemical fingerprinting that links activity to specific tannins/phenolics and chronic topical safety/stability data. Accordingly, the immediate priority is to confirm efficacy and safety in adequately powered dermatological trials while standardising the extract. This step is necessary to permit regulatory acceptance and safe commercialisation of cosmeceutical formulations.

Ficus racemosa demonstrates a broad preclinical pharmacology (antidiabetic, antimicrobial, antiulcer and antinociceptive) and contains notable bioactives such as β-sitosterol and triterpenes; fermentation has been reported to enhance efficacy (33, 39). Critical gaps include definitive isolation and mechanistic validation of the antidiabetic and antimicrobial constituents, standardised toxicology across collection sites and clinical proof-of-

Table 3. Pharmacological activities of fruits of 7 *Ficus* species

Species	Antioxidant	Anti-inflammatory	Antidiabetic	Antimicrobial	Antiulcer	Analgesic	Cosmeceutical / dermatological	References
Ficus assamica	Strong	Protein denaturation inhibition	-	-	-	-	-	(14, 22)
Ficus auriculata	Strong	-	-	Broad spectrum (against *Escherichia coli*, *Shigella flexneri*, *Staphylococcus epidermidis*)	-	-	-	(9, 26, 34, 35)
Ficus fistulosa	Strong	Sebum reduction/ astringent reduction	-	-	-	-	Sebum control (hydrogel)	(6, 15)
Ficus hispida	Strong	Significant	Moderate	Moderate	Reported	Yes	Dermatological, wound healing	(8, 14, 16, 27, 36)
Ficus racemosa	Strong	Moderate	Strong	Broad spectrum (bacteria, fungi)	Yes	Strong	-	(12, 19, 30, 37)
Ficus semicordata	Strong	-	Moderate	-	-	-	-	(11, 14, 21)
Ficus simplicissima	Strong	-	-	Broad spectrum (antifungal)	-	-	Sebum control, antioxidant hydrogel potential	(4, 14, 15)

concept data. Priority should center on isolating and validating the antidiabetic lead(s) and advancing an evidence-based extract into pilot human trials. Human efficacy data will determine whether *F. racemosa* can meaningfully contribute to nutraceutical or therapeutic portfolios.

Ficus semicordata is notable for tannins, alkaloids, dose-dependent antioxidant activity and high mineral content (notably calcium and iron), suggesting nutritional as well as pharmacological value (10, 21, 40). Comprehensive metabolomic mapping beyond broad phytochemical categories, mechanistic data for reported bioactivities and contaminant/safety surveys across harvest sites are missing. The principal research priority is therefore thorough chemical and mineral mapping combined with safety confirmation. This focus is necessary before recommending broader dietary use or integration into nutrition programs.

Ficus simplicissima yields a high-value translational lead: bergapten has been advanced into an inhalable bergapten-liposome (Ber-lipo) that ameliorates LPS-induced acute lung injury via macrophage reprogramming and suppression of TLR4/MyD88/NF-κB signaling (4). The outstanding gaps are inhalation-specific toxicology and pulmonary pharmacokinetics (PK), formulation stability and manufacturing scale-up data and early human safety evaluation. The highest priority is to de-risk the inhalation candidate through inhalation toxicology and PK studies. Addressing these gaps is the critical path to converting a compelling preclinical mechanistic signal into a feasible clinical intervention (Table 4).

Across species, three universal bottlenecks emerge: lack of harmonised quality and reporting standards, insufficient safety and toxicological evaluation and a near-complete absence of human clinical validation. Moreover, from a commercialisation perspective, sustainability and intellectual property issues are critical, as most studies do not report sourcing, harvest pressure or benefit-sharing arrangements and few consider protectable claims beyond broad traditional use. Without validated composition, safety and human efficacy data, promising preclinical findings cannot be translated into market-ready nutraceuticals, cosmeceuticals or therapeutics.

Conclusion

The fruits of the *Ficus* species constitute an underutilised yet nutritionally rich resource with significant ethnomedicinal relevance. Across the 7 species examined, strong antioxidant, anti-inflammatory and metabolic-regulatory activities are supported by diverse polyphenolic and flavonoid profiles. Among them, *Ficus fistulosa* shows verified human dermatological efficacy, *F. auriculata* and *F. racemosa* demonstrate potent enzyme-inhibitory and antidiabetic effects and *F. simplicissima* offers an advanced therapeutic prototype through bergapten-based nanomedicine. Despite these advances, the absence of harmonised analytical protocols, compound-level identification, toxicological validation and clinical trials remains the principal barrier to translational progress. Future research must prioritise harmonised protocols, metabolomic fingerprinting, mechanistic elucidation and systematic safety evaluation to enable evidence-based nutraceutical and pharmaceutical applications. Strengthening these areas will validate traditional knowledge, promote sustainable exploitation of *Ficus* biodiversity and contribute to affordable, plant-based interventions for chronic diseases.

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Authors' contributions

MSO was responsible for the drafting and formatting of the manuscript. MML and MIK contributed to the collection of relevant data and visual materials. MMK conducted a critical review of the manuscript and performed necessary revisions. MA provided supervision, guidance and overall direction throughout the study. All authors read and approved the final manuscript.

Table 4. Research gaps and prioritised future research directions for the fruits of 7 *Ficus* species

Ficus species	Key known findings	Major research gaps	Priority future directions
Ficus assamica	High phenolic (120 mg GAE g^{-1}) and flavonoid (428 mg QE g^{-1}) contents; strong antioxidant and anti-inflammatory activity.	No identification of individual phenolic compounds.	Isolate and characterise major phenolics; evaluate the mechanism of inflammation inhibition and perform toxicity screening.
Ficus hispida	Chemically diverse (isoflavones, coumarins, phenolics); antioxidant, cytotoxic and neuropharmacological effects.	Inconsistent quantitative profiling; lack of ADME/toxicity studies.	Standardise extract composition; prioritise bioactive leads; conduct safety and pharmacokinetic assessments.
Ficus auriculata	High antioxidant and antimicrobial activity; isoflavones and phenolics are well characterised.	Limited cross-study comparability; no human data for antidiabetic claims.	Harmonise extraction protocols; perform *in vivo* and small-scale human trials on antidiabetic efficacy and safety.
Ficus fistulosa	High phenolic content and demonstrated clinical sebum-reducing effect (≈ 54%).	No large-scale trials; unclear chemical-activity linkage; long-term safety untested.	Identify active compounds; conduct controlled dermatological studies; assess chronic topical safety.
Ficus racemosa	Broad pharmacological profile (antidiabetic, antimicrobial, antiulcer); contains β-sitosterol and triterpenes.	Unclear active constituents; limited mechanistic and toxicological validation; no clinical data.	Isolate active antidiabetic compounds; standardise extracts; initiate pilot human studies.
Ficus semicordata	Rich in minerals (Ca, Fe) and tannins; strong antioxidant and antidiabetic potential.	Poor metabolomic mapping; no contamination/safety data; limited mechanistic work.	Perform full phytochemical and mineral profiling; evaluate safety and dietary potential.
Ficus simplicissima	Bergapten-based liposomal formulation (Ber-lipo) is effective against acute lung injury.	Lacks inhalation toxicology, pharmacokinetics and scale-up data.	Conduct inhalation safety/PK studies; optimise formulation stability; initiate early human safety trials.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

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During the preparation of this work the authors used Grammarly and ChatGPT in order to grammar correction and formatting. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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