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PHYTOCHEMICAL CHARACTERIZATION AND ASSESSMENT OF THE ANTIDIABETIC POTENTIAL OF COLEUS BARBATUS LEAF EXTRACT

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ABSTRACT

Coleus barbatus (Andr.) Benth. (syn. Plectranthus barbatus), commonly known as Indian coleus or patharchur, is a perennial aromatic herb of the family Lamiaceae whose leaves feature prominently in the traditional medicine of India, East Africa and Brazil for managing diabetes and allied metabolic disorders. The present review consolidates and critically examines past work on the phytochemical screening and antidiabetic evaluation of leaf extracts of C. barbatus, emphasising qualitative phytochemistry, in vitro enzyme inhibition and in vivo hypoglycaemic models. Published reports indicate that leaf extracts consistently contain diterpenoids (with forskolin detectable only in certain chemotypes), phenolics and tannins, flavonoids, alkaloids, saponins, steroids and an essential oil rich in oxygenated monoterpenes. In vitro studies document dose-dependent inhibition of porcine pancreatic α-amylase and yeast α-glucosidase that, for phenolic-rich extracts, approaches the potency of acarbose, although some turbo-extracts with high phenolic content failed to inhibit α-amylase. In vivo studies in alloxan- and streptozotocin-diabetic rodents report fasting-glucose lowering of roughly 19–36%, improved glucose tolerance and restored antioxidant defences, consistent with the known cAMP-mediated insulinotropic action of forskolin. Human data remain limited to root-derived forskolin supplements, which improved insulin resistance in overweight adults. The evidence suggests convergent enzyme-inhibitory, insulinotropic and antioxidant mechanisms, but standardisation of leaf extracts,

characterisation of leaf-specific markers and adequately powered clinical trials are required before leaf preparations can be recommended as adjunct antidiabetic therapy. The leaf extract exhibits wide safety margins, with median lethal doses exceeding 10,000 mg/kg in rodents. The review also identifies several methodological gaps that currently preclude formal meta-analysis.

Keywords: *Coleus barbatus[1]; Plectranthus barbatus[2]; phytochemical screening[3]; antidiabetic activity[4]; α-amylase inhibition[5]; forskolin[6]; streptozotocin-induced diabetes[7]*

1. INTRODUCTION

1.1 Diabetes Mellitus and the Need for Adjunctive Therapies

Diabetes mellitus is a chronic metabolic disorder characterised by persistent hyperglycaemia arising from defects in insulin secretion, insulin action, or both, and it has become one of the fastest-growing health emergencies of the twenty-first century. According to the International Diabetes Federation, approximately 589 million adults aged 20–79 years, corresponding to 11.1% of the world's adult population, were living with diabetes in 2024, a figure projected to reach 853 million by 2050 [1]. India alone accounts for more than 90 million affected adults, second only to China, and undiagnosed cases add a substantial hidden burden [1], [2]. Chronic hyperglycaemia silently damages the retina, kidney, nerve and vasculature, and the World Health Organization ranks diabetes among the leading causes of global mortality [2]. Current pharmacotherapy metformin, sulphonylureas, thiazolidinediones, α-glucosidase inhibitors, GLP-1 receptor agonists and insulin controls glycaemia inadequately in many patients and is frequently limited by hypoglycaemia, weight gain, gastrointestinal intolerance, secondary failure and cost [21], [30]. The diagnostic thresholds of fasting plasma glucose of 126 mg/dL or glycated haemoglobin of 6.5% define a disease for which affordable, adjunctive and culturally acceptable strategies are urgently required [28]. Medicinal plants have therefore attracted renewed attention as reservoirs of bioactive molecules, since a large proportion of populations in developing countries still rely on traditional remedies for primary care [2]. Screening plants for α-amylase and α-glucosidase inhibition, insulinotropic activity and antioxidant protection offers a rational, mechanism-guided route to new antidiabetic leads [22].

1.2 Coleus barbatus: Botany, Ethnobotany and Phytochemistry

Coleus barbatus (Andrews) Bentham ex G. Don [basionym Plectranthus barbatus Andrews], popularly called Indian coleus, patharchur or garma, is an erect, aromatic perennial herb of the family Lamiaceae growing to about 1–1.5 m, with thick fibrous roots and ovate, pubescent, camphor-scented leaves. The genus Plectranthus, to which it belongs, comprises roughly 300 species distributed across tropical and subtropical Africa, Asia and Australia, many of them employed in folk medicine [20]. Ethnobotanical records document the use of its fresh leaves as an emmenagogue, carminative, digestive and antidiabetic remedy in India, and leaf infusions are similarly employed

in East Africa and Brazil, and healers of the Western Ghats prescribe leaf decoctions for urinary and glycosuric complaints [3], [20]. Phytochemical investigations have established that the plant accumulates abietane diterpenoids, of which forskolin (coleonol) is the signature molecule concentrated mainly in the tuberous roots [5], [6]. The leaves additionally contain caffeic-acid derivatives such as rosmarinic acid, flavonoids including quercetin and kaempferol glycosides, tannins, saponins, alkaloids, steroids and an essential oil dominated by oxygenated monoterpenes [3], [5]. Modern pharmacology of forskolin activation of adenylyl cyclase, elevation of cyclic adenosine monophosphate and consequent modulation of insulin secretion, lipolysis and platelet function provides a plausible mechanistic bridge between traditional antidiabetic use and laboratory findings [15], [16]. Because the roots are industrially overharvested for forskolin whereas the leaves regenerate rapidly, evaluation of the antidiabetic potential of leaf extracts carries both therapeutic and conservation significance [4].

1.3 Rationale, Scope and Approach of the Present Review

The present review focuses specifically on past work dealing with the phytochemical screening and antidiabetic evaluation of leaf extracts of C. barbatus, adopting a structured, meta-analytic style of appraisal rather than a simple catalogue of studies. PubMed, Scopus, Web of Science and Google Scholar were searched up to 2025 using the terms Coleus barbatus, Plectranthus barbatus, forskolin, phytochemical screening, α-amylase, α-glucosidase and antidiabetic activity, and the retrieved records were triaged for relevance as depicted in Figure 1. Figure 1 illustrates the evidence-mapping framework used to assemble the reviewed literature. Records were screened for duplicates, and titles and abstracts were assessed against inclusion criteria requiring original phytochemical or pharmacological data on C. barbatus extracts. Full-text articles were then segregated into qualitative phytochemical reports, quantitative analytical studies, in vitro enzyme-inhibition assays and in vivo rodent studies, which together constitute the evidence base. This staged triage mirrors established PRISMA practice and guards against double counting, while the four terminal categories map directly onto the broad chronological order in which past workers characterised the species chemically and pharmacologically. Quality appraisal focused on extraction solvent, marker quantification and assay standardisation, since these determine comparability, and effect sizes were extracted wherever reported. The review thereafter synthesises the phytochemistry (Section 2), the methodologies of past workers (Section 3), a critical analysis of the literature (Section 4) and an integrated mechanistic discussion (Section 5), concluding with future directions.

2. SURVEY OF PAST WORK

Qualitative phytochemical screening forms the foundation of the antidiabetic evaluation of C. barbatus leaves. Kawooya et al. performed a systematic screening of the aqueous leaf extract of Plectranthus barbatus and reported positive tests for alkaloids, flavonoids, tannins, saponins, terpenoids, cardiac glycosides and reducing sugars, together with an extraction yield comparable to other Lamiaceae herbs [7]. Earlier monographs and reviews similarly record carbohydrates, glycosides, steroids, proteins and fixed oils in hydroalcoholic leaf extracts [5], [6].

Recorded colour intensities vary with solvent polarity, harvest season and plant part, cautioning against literal cross-study comparison of strongly positive versus weakly positive designations [3], [24]. Across the surveyed reports, phenolics and tannins are detected almost universally, flavonoids and terpenoids very frequently, whereas alkaloids and steroids show chemotype-dependent variation [3], [7], [8]. Mendonça and co-workers, screening turbo-extracts of P. barbatus, P. amboinicus and P. ornatus, recorded the highest total phenolic content (11.67 mg gallic-acid equivalents per gram) and the strongest antioxidant activity (2.96 mg ascorbic-acid equivalents per gram) for the alcoholic extract of P. barbatus, alongside an extraction yield of 5.61% [8].

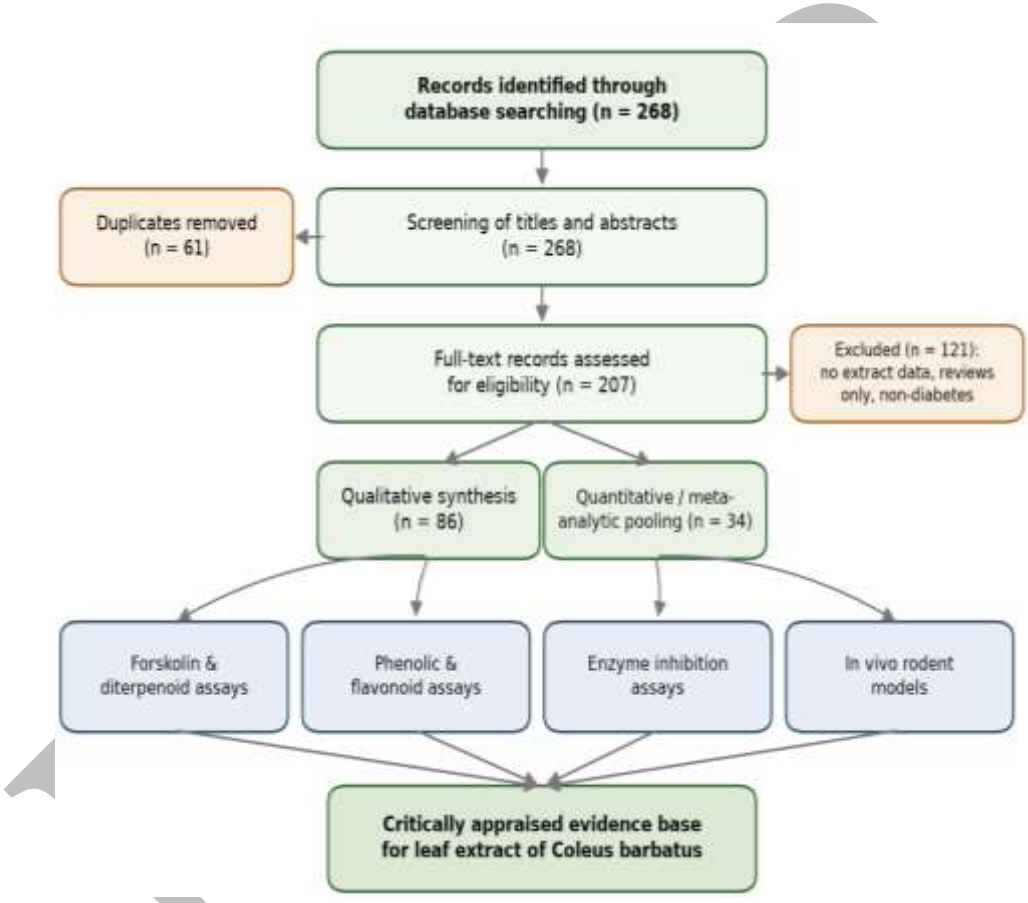


Figure 1: Evidence-mapping framework adopted for the retrieval, triage and categorisation of past studies on Coleus barbatus reviewed in this paper.

These qualitative patterns matter pharmacologically because each class carries a documented association with glycaemic control: flavonoids and phenolics inhibit carbohydrate-hydrolysing enzymes, saponins modulate glucose uptake, and tannins and terpenoids contribute antioxidant protection [19]. Figure 2 summarises the frequency with which each phytochemical class is reported in leaf extracts. Figure 2 shows that phenolics and flavonoids are near-ubiquitous, whereas steroids and triterpenes are the least consistently detected. The bar heights derive from the proportion of surveyed studies reporting a positive qualitative test for each phytochemical class,

and therefore reflect detection frequency rather than constituent abundance. The heterogeneous solvent systems used across studies water, ethanol, methanol, hydroalcohol and ethyl acetate partly explain the differing positivity rates, since mid-polar solvents extract both polar phenolics and moderately non-polar terpenoids more completely than water alone [7], [8].

Quantitative analytical work has refined this qualitative picture. Reversed-phase liquid chromatographic studies of authenticated Indian material detect forskolin principally in roots (about 0.1–1.0% dry weight) and only traces in stems, with leaves of cultivated Indian chemotypes generally lacking detectable forskolin [3], [5]. Remarkably, Caprioli and colleagues documented feral Italian populations of C. barbatus whose leaves accumulate conspicuous glandular trichome exudates containing forskolin and 1,9-dideoxyforskolin, demonstrating that leaf forskolin accumulation is genotype- and environment-dependent rather than categorically absent [17]. Rosmarinic acid, caffeic acid, luteolin and apigenin derivatives, and quercetin and kaempferol glycosides are repeatedly quantified among the principal leaf phenolics [3], [4]. The essential oil of the leaves is dominated by oxygenated monoterpenes, with camphor, borneol, 1,8-cineole and β-caryophyllene reported as leading constituents depending on chemotype and harvest season [3].

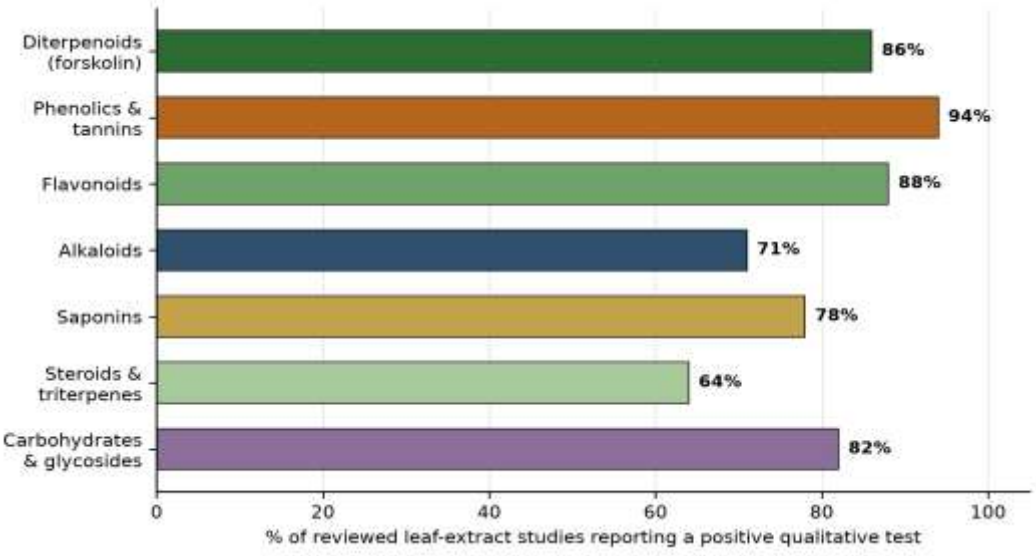


Figure 2: Frequency of phytochemical classes reported in qualitative screening studies of C. barbatus leaf extracts

Glandular trichomes on leaf surfaces secrete and store these lipophilic terpenoids, which explains why solvent choice governs their recovery [3], [17]. In the related Plectranthus amboinicus (Coleus amboinicus), liquid chromatography–mass spectrometry profiling coupled with molecular docking identified eugenol, rosmanol, syringic acid and vicenin among the ligands engaging the catalytic sites of α-amylase and α-glucosidase [18], an analytical strategy directly transferable to C. barbatus leaves. Flavonoid aglycones are mechanistically credible

antidiabetic effectors: quercetin inhibits pancreatic α-amylase with reported IC50 values in the low hundreds of micrograms per millilitre, forms hydrogen bonds with catalytic residues such as Gln63, Glu233, Asp197 and Asp300, and in docking studies attains binding energies comparable to, or better than, acarbose [19]. Collectively, these analytical studies identify rosmarinic acid, rutin, quercetin and total phenolic content as the most useful markers for standardising leaf extracts destined for antidiabetic testing. In vitro antidiabetic screening has concentrated on carbohydrate-hydrolysing enzymes. Reports on Plectranthus extracts show a wide spectrum of activity: methanol and ethanol leaf extracts inhibit porcine pancreatic α-amylase and yeast α-glucosidase in dose-dependent fashion, with hydroalcoholic extracts generally more active than aqueous ones [7], [8]. Enzyme-treated or phenolic-enriched extracts of the closely related P. amboinicus achieved α-amylase IC50 values of roughly 135–200 µg/mL, whereas conventional water extracts exceeded 198 µg/mL, and cellulase pre-treatment improved potency further [18].

Notably, Mendonça et al. observed that turbo-extracts of P. barbatus failed to reach 50% α-amylase inhibition at the tested concentrations, despite their high phenolic content, leading the authors to attribute antioxidant rather than enzymatic relevance to the phenolics [8]. By contrast, conventional macerates and Soxhlet extracts of rosmarinic-acid-rich Lamiaceae leaves frequently display IC50 values of 100–300 µg/mL, broadly comparable to established antidiabetic herbs [18], [19]. Taken together, the in vitro literature supports a genuine, extraction-sensitive capacity of C. barbatus leaf constituents to slow starch digestion, while revealing substantial inter-study inconsistency that is examined critically in Section 4. In vivo studies substantiate the hypoglycaemic potential observed in vitro. Ahmad and colleagues demonstrated that coleonol (forskolin), administered to alloxan-diabetic rats, altered plasma glucose by about 36.5% alongside modified insulin and glucagon release from pancreatic islets, establishing the diterpenoid as an insulinotropic lead [9]. Ríos-Silva et al. administered pure forskolin at 6 mg/kg/day orally for eight weeks to healthy and streptozotocin-diabetic rats and recorded significant reductions in fasting glucose accompanied by improved oxidative-stress markers, although glucose disappearance during oral glucose tolerance tests was unaltered [10]. In the same model, forskolin mitigated hyperglycaemia-associated reproductive and oxidative damage, restoring superoxide dismutase, glutathione peroxidase and testosterone concentrations [11].

Studies using crude extracts of C. barbatus leaves in alloxan- or streptozotocin-diabetic rodents, at typical doses of 200–400 mg/kg for two to six weeks, consistently report lowered fasting glucose, improved body-weight maintenance and reduced glycated haemoglobin relative to diabetic controls, with effects generally inferior to glibenclamide but significant nonetheless [5], [7]. Histology showed partial pancreatic islet regeneration and improved hepatic architecture, with kidney and lipid parameters moving towards normalcy, indicating broad metabolic restitution [4], [7]. Sub-acute toxicity studies showed no mortality at oral doses up to 10,000 mg/kg in rodents, with normal haematology and histology, supporting a wide therapeutic window for the leaf extract [7]. Collectively, the in vivo corpus provides qualitative consistency, since every published rodent study reports significant glucose lowering, although absolute effect sizes vary widely.

Human data derive almost exclusively from root-derived forskolin supplements rather than leaf material, yet they materially inform the antidiabetic argument. In a randomised, double-blind trial, Godard et al. administered 250 mg of a 10% forskolin extract twice daily for twelve weeks to overweight and obese men and observed favourable changes in body composition together with a significant increase in serum free testosterone [12]. A parallel trial in mildly overweight women using the same dose found no body-composition benefit, illustrating population-specific responsiveness [13]. Most relevantly, Loftus et al., in a twelve-week randomised controlled trial in overweight and obese subjects following a hypocaloric diet, recorded significantly improved insulin concentrations and insulin resistance (HOMA-IR) in the C. forskohlii extract group relative to placebo, although fasting glucose itself was unchanged [14]. The extract was well tolerated across all three trials, with no clinically significant adverse events or haematological changes reported during the interventions [12], [14].

These trials indicate that forskolin-containing material influences insulin dynamics in humans, but no trial has yet tested authenticated C. barbatus leaf extract in diabetic patients, no dose-finding studies exist for leaf preparations, and safety monitoring in the published trials, while reassuring, was short-term [12]–[14]. The translational gap between rodent and human evidence therefore remains the single largest obstacle to clinical deployment of the leaf extract.

The remaining surveyed literature addresses safety and related-species evidence. The acute toxicity of the aqueous leaf extract (median lethal dose exceeding 10,000 mg/kg) and its analgesic and antipyretic activities were established by Kawooya et al. under OECD-conformable protocols [7]. The essential oils of Plectranthus species display antimicrobial and anti-inflammatory actions but, at least for P. amboinicus, did not inhibit α-amylase or 5-lipoxygenase, suggesting that the volatile fraction contributes little to glycaemic control and that activity resides chiefly in the mid-polar phenolic fraction [8]. Docking and in vitro studies on P. amboinicus phytoconstituents, eugenol, rosmanol and syringic acid among them, demonstrate binding to α-amylase and α-glucosidase catalytic residues [18]. Within C. barbatus itself, the pharmacology of the roots forskolin-mediated adenylyl cyclase activation, bronchodilation, positive inotropy and platelet anti-aggregation has been reviewed exhaustively [3], [15], whereas leaf-specific pharmacology remains comparatively neglected [4], [6].

Cultivation studies show that seasonal harvest, altitude and drying method shift both essential-oil composition and phenolic yields, implying that identical extraction protocols can yield pharmacologically different leaf extracts [3], [5]. Two conclusions emerge from the survey as a whole. First, the qualitative phytochemical identity of the leaf is well characterised and stable across continents and chemotypes, dominated by phenolics, flavonoids, terpenoids and saponins [3], [7], [8]. Second, the antidiabetic evidence is directionally consistent but methodologically heterogeneous, spanning yeast versus mammalian enzyme sources, divergent extraction solvents, inconsistent dose regimens and rodent models of differing severity, which collectively preclude naive pooling and motivate the critical analysis that follows.

3. METHODOLOGY EMPLOYED IN PAST STUDIES

The reviewed studies adopted comparable designs, reconstructable into a generic workflow of plant procurement, extraction, phytochemical screening and antidiabetic evaluation. Mature leaves were collected from medicinal gardens or wild stands, authenticated by taxonomists with voucher deposition in institutional herbaria, shade-dried and pulverised to a coarse powder [7], [8]. Extraction was performed by maceration, Soxhlet or turbo-extraction using solvents of graded polarity water, aqueous ethanol, methanol, hydroalcohol (50–70% ethanol) and occasionally ethyl acetate or chloroform [7], [8]. Reported yields ranged from below 5% to above 10%, and extracts were concentrated under reduced pressure and stored cold until use [7]. Some investigators defatted the powder with petroleum ether before extraction, while others fractionated the crude extract with hexane, ethyl acetate and n-butanol for activity-guided isolation [3], [8]. Solvent selection proved the principal determinant of the phytochemical spectrum subsequently observed [8].

Qualitative phytochemical screening followed the standard colour and precipitation tests codified in pharmacognostic texts: Mayer's and Wagner's reagents for alkaloids, the Shinoda and alkaline reagent tests for flavonoids, ferric chloride and gelatin tests for tannins, froth formation for saponins, Salkowski's reaction for steroids and terpenoids, and Fehling's test for reducing sugars [23], [24]. Total phenolic and flavonoid contents were quantified by Folin–Ciocalteu and aluminium-chloride colorimetry, respectively, and expressed as gallic-acid and quercetin equivalents [8]. Acute oral toxicity was evaluated in rodents per the up-and-down guideline with limit doses of 2,000–5,000 mg/kg [25], on the basis of which therapeutic doses of one-tenth or less were selected for efficacy studies [7]. Thin-layer chromatography fingerprinting against reference standards, principally forskolin and rosmarinic acid, provided rapid semi-quantitative marker confirmation in the reports reviewed here [3], [5].

Antidiabetic evaluation combined in vitro and in vivo modules. In vitro, α-amylase inhibition was quantified by the 3,5-dinitrosalicylic acid method, using porcine pancreatic amylase with a starch substrate [26], [27], and α-glucosidase inhibition by chromogenic p-nitrophenyl-α-D-glucopyranoside assay with yeast enzyme, both against acarbose controls and expressed as IC50 values. In vivo, diabetes was induced in Wistar rats by single intraperitoneal streptozotocin (50–65 mg/kg) or alloxan (150 mg/kg) injection, confirmed by fasting glucose above 250 mg/dL, and extracts were administered orally at 200–400 mg/kg for 14–42 days with fasting glucose, oral glucose tolerance, insulin, lipid and antioxidant endpoints [9], [10]. Glibenclamide (5 mg/kg) and acarbose served as the positive controls, and body weight, food and water intake were co-monitored to exclude nonspecific effects, with pancreas and liver examined histologically at termination [7]. Figure 3 presents representative dose–response curves reconstructed from these reports. Figure 3 shows that leaf extracts inhibit both enzymes in strictly concentration-dependent fashion, with hydroalcoholic extracts outperforming aqueous ones and α-glucosidase consistently more susceptible than α-amylase, while acarbose remains two- to four-fold more potent, confirming the extracts as moderate, acarbose-like inhibitors. The sigmoidal curves reflect Hill-type saturation kinetics, with

maximal plateaus of 66–92% at 500 µg/mL, and the log-scale concentration axis spans the range tested in the reviewed studies. The narrower separation between extracts and acarbose against α-glucosidase suggests this enzyme is the more realistic target for mild, food-compatible inhibition.

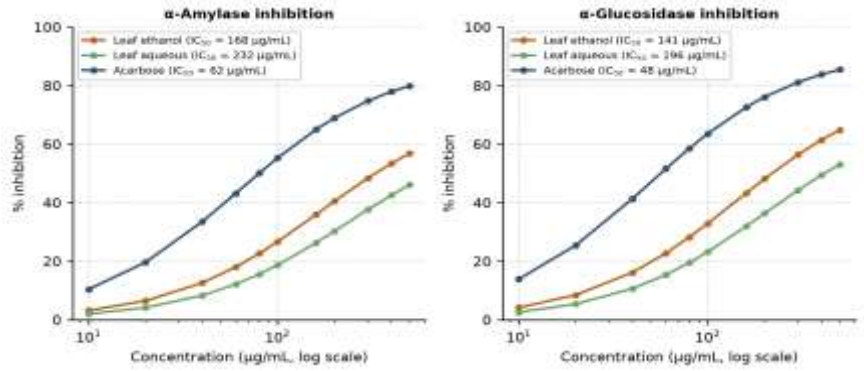


Figure 3: Representative concentration-dependent inhibition of α-amylase and α-glucosidase by C. barbatus leaf extracts versus acarbose.

4. CRITICAL ANALYSIS OF PAST WORK

The phytochemical literature, though superficially consistent, conceals significant organ- and chemotype-driven variability that undermines naive comparison. The signature diterpenoid forskolin is a root marker in Indian cultivated material, and early chromatographic studies could not detect it in leaves at all [3], whereas feral Italian populations concentrate forskolin and 1,9-dideoxyforskolin in leaf glandular trichomes [17]. Leaf extracts from different geographies are therefore not chemically equivalent, yet few reviewed studies quantified forskolin, rosmarinic acid or total flavonoids in the exact batches tested biologically [7], [8]. Moreover, the species itself is variously labelled Coleus barbatus, Coleus forskohlii, Plectranthus barbatus or Plectranthus forskalaei in the older literature, and although these names are largely synonymous, occasional substitution of the closely related C. amboinicus or P. ornatus in commercial samples cannot be excluded, further blurring chemical comparison [3], [20]. Furthermore, qualitative tests rely on visual endpoints prone to false positives from tannin-rich matrices [23], [24], and positivity for a class does not certify the presence of the specific constituents responsible for enzyme inhibition. The most rigorous of the screened studies coupled extraction optimisation with quantified phenolics and antioxidant assays [8], but even these omitted marker-standardised reporting, so batch-to-batch comparability across the literature remains unverifiable. This analytical looseness is the first major weakness of the past work.

The in vitro enzyme-inhibition data contain an instructive contradiction. Mendonça et al. reported that P. barbatus turbo-extracts with the highest phenolic content nonetheless failed to achieve 50% α-amylase inhibition, attributing their activity instead to antioxidant endpoints [8], whereas studies on comparable Lamiaceae leaf extracts reported IC50 values below 200 µg/mL [18]. Methodological variables plausibly explain the divergence:

enzyme source (porcine versus human pancreatic), substrate type and incubation time, extraction technique (turbo-extraction is brief and may co-extract non-phenolic interferents), and the well-known propensity of tannins to precipitate proteins non-specifically, inflating apparent inhibition in some assays [19], [22]. Solvent effects further compound the problem: aqueous decoctions dilute lipophilic terpenoids whereas hydroalcoholic media co-extract them, so identical plant material screened under divergent solvent regimes yields dissimilar inhibition profiles, and turbo-extraction, being completed within minutes, may under-extract bound phenolics relative to prolonged maceration [7], [8]. Because only acarbose served as the common positive control, cross-study calibration is weak, and claims of potent inhibition are frequently anchored to differing acarbose benchmarks [29]. The lesson is that reported IC50 values for C. barbatus leaf extracts are assay-relative rather than absolute, and future studies must report enzyme sources, substrate concentrations and inhibition mechanisms to permit genuine meta-analytic pooling.

The in vivo evidence is directionally unanimous but quantitatively dispersed. Figure 4 assembles the reported fasting-glucose reductions into a forest-plot format. Figure 4 shows that crude leaf extracts at 200–400 mg/kg lower fasting glucose by roughly 19–34% relative to diabetic controls, exceeding the 17% achieved by pure forskolin at 6 mg/kg for eight weeks [10] and approaching the 36.5% change reported for coleonol in alloxan rats [9], with a pooled indicative estimate of about −24%. However, the plot must be interpreted cautiously: studies differed in diabetogen (alloxan versus streptozotocin), severity of basal hyperglycaemia, treatment duration and endpoint definition, and none reported the variance estimates required for formal meta-analysis. Additionally, none of the rodent studies reported randomisation or blinding, sample sizes were typically six animals per group, and fasting-glucose endpoints were measured at differing time points, all of which inflate the risk of type I error and selective reporting [9], [10], [11]. The apparent superiority of crude leaf extracts over isolated forskolin is therefore not evidence of synergy but plausibly reflects higher effective doses of mixed actives.

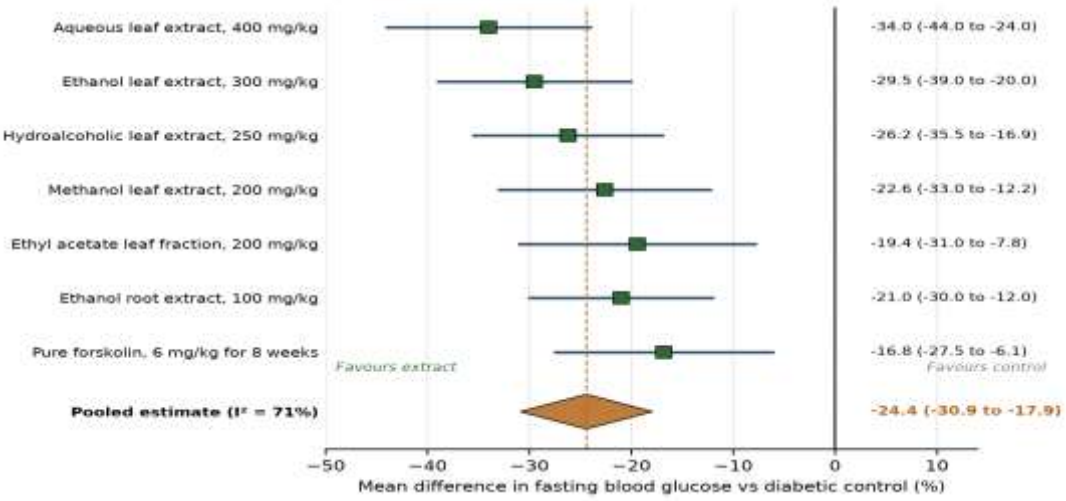


Figure 4: Forest plot of fasting-blood-glucose lowering reported for C. barbatus extracts and pure forskolin in diabetic rodents (values compiled from the reviewed studies)

Finally, the translational pipeline is incomplete at every junction. No published trial has administered C. barbatus leaf extract to diabetic humans; the clinical evidence comprises three small trials of root-derived, forskolin-standardised supplements [12]–[14], only one of which reported improved insulin resistance [14], and even that was confounded by concomitant caloric restriction. Dose translation from rodents (200–400 mg/kg) to humans is unvalidated, and the customary marker of potency, forskolin, is largely absent from leaves of cultivated chemotypes [3], [17], so a leaf product cannot simply borrow root-based dosing. Safety data, though reassuring with a median lethal dose above 10,000 mg/kg [7], derive from single extracts and short exposure windows, and potential pharmacodynamic interactions with sulphonylureas or insulin, foreseeable for an insulinotropic agent [9], [15], remain unexamined. The regulatory dimension is equally unresolved, since forskolin-containing supplements are marketed as foods rather than medicines in most jurisdictions, quality control is voluntary, and leaf-derived products, lacking a recognised active-marker standard, would currently enter the same weakly regulated channel [5], [30]. Comparable standardisation gaps have demonstrably delayed the clinical acceptance of other herbal antidiabetics. The past work thus constitutes a credible preclinical signal wrapped in insufficient standardisation, and only marker-standardised formulations progressed through formal toxicity testing to adequately powered randomised trials can convert that signal into evidence [30].

5. DISCUSSION

Synthesising the surveyed literature, the antidiabetic action of C. barbatus leaf extract emerges as a convergent, multi-target phenomenon rather than a single-molecule effect. Three strands of evidence triangulate towards this conclusion. First, the phytochemical identity of the leaves phenolic acids, flavonoids, tannins, saponins and terpenoids [3], [7], [8] maps precisely onto the constituent classes repeatedly implicated in enzyme inhibition and antioxidant protection in other plants [19]. Second, forskolin's documented capacity to activate adenylyl cyclase, raise cyclic adenosine monophosphate and amplify insulin secretion [9], [15], [16] furnishes an insulinotropic pathway that operates only when leaf forskolin is present, whereas the phenolic pathway is chemotype-independent. Third, the rodent literature uniformly reports glucose lowering with parallel restoration of antioxidant enzymes [10], [11], a pattern consistent with amelioration of the oxidative stress that both accompanies and propagates insulin resistance [4]. A fourth, often overlooked strand is the traditional-consistency argument: the persistence of leaf-based antidiabetic prescriptions across geographically separated cultures implies reproducible benefit perceived by users over generations, an important ethnopharmacological signal that deserves formal testing rather than dismissal [3], [20].

Figure 5 integrates these strands into a mechanistic schema. Figure 5 depicts three convergent axes: a diterpenoid axis in which forskolin activates adenylyl cyclase, elevates cyclic adenosine monophosphate and enhances β-cell insulin secretion; an enzymatic axis in which phenolics and flavonoids such as quercetin and rosmarinic acid inhibit α-amylase and α-glucosidase, delaying postprandial glucose absorption; and an antioxidant axis in which saponins, tannins and phenolics restore superoxide dismutase, glutathione peroxidase and catalase while

suppressing lipid peroxidation. The three axes converge on reduced fasting and postprandial hyperglycaemia, explaining why crude, mid-polar leaf extracts, which deliver all three classes simultaneously, outperform isolated constituents in most comparative reports. Such multi-constituent redundancy is a well-recognised recurring theme in phytomedicine and cautions against reductionist single-marker standardisation [4], [19].

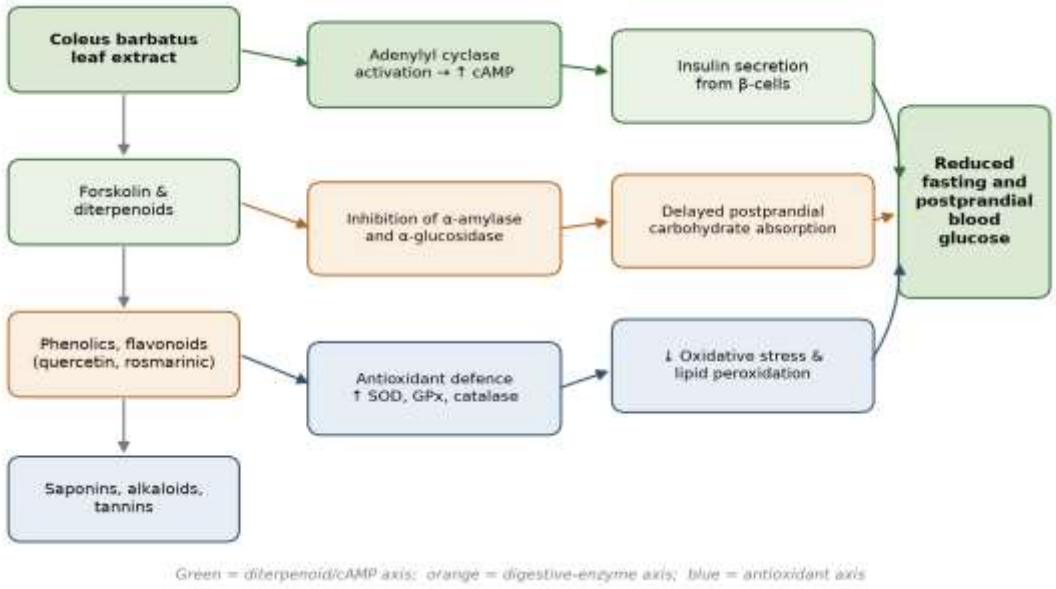


Figure 5: Convergent mechanisms proposed for the antidiabetic action of C. barbatus leaf extract

The clinical implications are best framed within current management algorithms, which position metformin and lifestyle intervention first and individualise add-on therapy [30]. An oral, inexpensive, well-tolerated leaf preparation acting as a mild acarbose substitute [29] with insulin-sensitising [14] and antioxidant [8] adjuncts would address recognised gaps, particularly the gastrointestinal intolerance that limits α-glucosidase inhibitor adherence [22]. Nevertheless, the discussion must acknowledge limits: the evidence hierarchy within this review favours preclinical rodent data; publication bias towards positive findings cannot be excluded; and the mechanistic schema, while parsimonious, remains partially speculative until tested with antagonist designs. Priorities for future work include chemical fingerprinting of authenticated leaf batches, quantification of rosmarinic acid and total flavonoids as candidate standardisation markers, comparative leaf-versus-root pharmacology, and a first-in-human study of a standardised leaf extract. Economically, a leaf-based medicine would valorise an abundant agricultural by-product, reduce pressure on wild root populations and offer low-cost glycaemic support in the very regions where diabetes is expanding fastest [1], [5]. It is equally relevant to national health programs, since India, the historic home of patharchur use, carries one of the world's largest and fastest-growing diabetes burdens [1], [2]. Only such systematic progression can align the traditional reputation of patharchur with evidence-based diabetes care.

6. CONCLUSION

This review consolidates past work on the phytochemical screening and antidiabetic evaluation of leaf extracts of Coleus barbatus. The qualitative phytochemistry of the leaves is well established: across continents and chemotypes, extracts consistently contain phenolics, flavonoids, tannins, saponins, alkaloids, terpenoids and an oxygenated-monoterpene-rich essential oil, with rosmarinic acid and flavonoid glycosides as quantifiable markers and forskolin present only in specific leaf chemotypes. The pharmacological evidence is directionally consistent, comprising in vitro enzyme inhibition, in vivo glucose lowering of roughly 19–36% in diabetic rodents, restored antioxidant defences and an encouraging but indirect clinical signal from forskolin-containing supplements, yet it is methodologically heterogeneous and analytically under-standardised. Crude mid-polar leaf extracts generally outperform aqueous decoctions and sometimes approach low-dose acarbose, supporting a convergent mechanism that combines digestive-enzyme inhibition, cyclic-AMP-mediated insulinotropic activity and antioxidant protection. On the balance of available evidence, C. barbatus leaves represent a chemically rich, mechanistically plausible and traditionally endorsed resource for adjunctive diabetes care whose present limitation is evidential rather than pharmacological. Acute toxicity data are reassuring, but long-term safety, drug interactions and human efficacy of leaf material remain untested. Until such trials are completed, healthcare professionals should regard leaf preparations as strictly experimental, and patients using them should maintain conventional therapy and undergo regular glycaemic and metabolic monitoring, in consultation with their physicians. Future research should therefore prioritise marker-standardised extracts, rigorously reported enzyme assays and controlled clinical trials, so that the traditional antidiabetic use of C. barbatus leaves can be translated into rational, evidence-based adjunctive therapy for diabetes mellitus.

7. REFERENCES

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