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Emerging Pharmacological Insights and Therapeutic Prospects of Cynodon dactylon (L.) Pers

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Abstract

Background: *Cynodon dactylon (L.) Pers.*, commonly known as Bermuda grass or "Dhub," is a medicinal herb widely used in Ayurvedic and traditional systems for managing chronic illnesses, diabetes, infections, and inflammatory conditions. Its diverse phytochemical profile comprising terpenoids, anthocyanins, phenolic acids, alkaloids, and flavonoids has drawn growing pharmacological interest.

Objective: This review systematically compiles and evaluates recent *in vitro*, *in vivo*, and limited clinical evidence regarding the phytochemical composition and pharmacological properties of *C. dactylon*, with emphasis on its bioactive constituents, molecular mechanisms, and translational potential, i.e., its ability to progress from experimental findings to standardised therapeutic formulations and future clinical applications.

Mechanism: The therapeutic effects of *C. dactylon* are mediated through modulation of key molecular pathways, including antioxidant defence (enhancement of CAT, SOD, GPx), anti-inflammatory signalling (downregulation of TNF-α, CRP, and nitric oxide pathways), metabolic regulation (inhibition of α-glucosidase and improved glucose uptake), and angiogenic signalling (upregulation of VEGF). These effects are primarily attributed to flavonoids such as apigenin, luteolin, orientin, and vitexin.

Key Findings: A comprehensive literature review (PubMed, Scopus, ScienceDirect, Google Scholar; 1990–2025) reveals potent antioxidant, anticancer, antidiabetic, anti-inflammatory, immunomodulatory, antimicrobial, wound-healing, and angiogenic activities across multiple preclinical models.

Conclusion: Despite robust preclinical evidence, significant gaps remain in extract standardisation, mechanistic depth, pharmacokinetics, and clinical validation. Future research should prioritise molecular-level investigations, rigorously designed clinical trials, and advanced delivery systems such as nanoformulations and biomaterial scaffolds. Overall, *C. dactylon* is a promising phytotherapeutic candidate with meaningful potential to bridge traditional medicine and modern drug development.

Keywords: *Cynodon dactylon*; flavonoids; pharmacological activities; antioxidant; herbal medicine.

1. Introduction

Bioactive compounds are naturally occurring chemical constituents in plants that exert biological effects in humans, including antioxidant, anti-inflammatory, and chemopreventive activities (Guaadaoui et al., 2014; Kris-Etherton et al., 2002; Liu, 2013; Sasidharan et al., 2010; Teodoro, 2019). These non-nutritional components can modulate physiological processes and contribute to disease prevention. Their relevance has increased alongside the global rise in chronic diseases such as cardiovascular disorders, diabetes, and cancer, which place immense pressure on healthcare systems, particularly in ageing and increasingly obese populations (Buer et al., 2007; Dixon & Steele, 1999; Winkel-Shirley, 2001). As the demand for novel therapeutic agents from natural sources continues to grow, exploring plants rich in secondary metabolites has become essential for identifying compounds with significant pharmacological potential (Biesalski et al., 2009; Quattrocchio et al., 2006).

Flavonoids constitute one of the largest and most widely distributed classes of plant secondary metabolites. Chemically, they are characterised by a C6–C3–C6 phenylbenzopyran backbone and are principally synthesised through the phenylpropanoid pathway (Buer et al., 2010; Burrell, 1937; Croft, 1998; Hidalgo et al., 2010; Li & Jiang, 2007; Panche et al., 2016; Treutter, 2005). They occur in

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fruits, vegetables, cereals, leaves, stems, bark, roots, tea, and wine (Bohm, 1998; Cook & Samman, 1996; Corcoran et al., 2012; Heim et al., 2002). Numerous *in vitro* and *in vivo* investigations have demonstrated that flavonoids exhibit potent antioxidant, anti-inflammatory, antimicrobial, anticancer, cardioprotective, and neuroprotective activities (Areias et al., 2001; Bravo, 1998; Gutierrez-Merino et al., 2011; Horowitz, 1972; Ishige et al., 2001; Kaleeswaran et al., 2012; Khatun et al., 2020; Lin et al., 2008; Rahman et al., 2015; Ross & Kasum, 2002; Rothwell et al., 2017; Schroeter et al., 2000; Spencer et al., 2001). Their mechanisms include free radical scavenging, enzyme modulation, regulation of cell signalling pathways, and gene expression control. Because of their structural diversity, broad distribution in nature, and substantial evidence of biological efficacy, flavonoids remain a central focus of natural product research aimed at addressing global chronic disease burdens **(Fig. 1 & 2).**

*Cynodon dactylon (*Linn.*) Pers. (C. dactylon*), commonly known as Bermuda grass or dhub grass, is a perennial herb found throughout warm regions worldwide (Chopra & Chopra, 2006; Harlan & de Wet, 1969; Parihar & Sharma, 2021; Singh et al., 2009; Warrier, 1993). The plant has lanceolate leaves, measuring 2-10 cm in length and 2-3 mm thick (**Fig. 3**). It has a long history of use in traditional medicinal systems for the treatment of inflammation, bleeding disorders, gastrointestinal disturbances, wounds, skin infections, and general weakness (Al-Snafi, 2016; Harlan, 1970; Jolly & Narayanan, 2000; Muthukrishnan et al., 2015; Shendye & Gurav, 2014). Phytochemical analyses show that *C. dactylon* contains alkaloids, flavonoids, glycosides, terpenoids, tannins, saponins, phenolics, carbohydrates, proteins, and essential oil. Earlier reports that suggested the absence of flavonoids and carotenoids were based on preliminary qualitative screenings; however, more advanced chromatographic analyses, including HPLC, LC-MS, and TLC, have confirmed the presence of both flavonoids and carotenoids in varying concentrations depending on extraction solvents and plant parts.

These bioactive constituents contribute to the plant's broad pharmacological profile, encompassing antidiabetic, hepatoprotective, antioxidant, anti-inflammatory, antimicrobial, immunomodulatory, and anticancer properties. Owing to its rich phytochemical content, widespread availability, and extensive medicinal use, *C. dactylon* (**Table 1**) holds significant promise for the discovery of new therapeutic agents.

Given the increasing scientific interest in plant-derived bioactive compounds and their potential role in mitigating diseases associated with oxidative stress and inflammation, further investigation of the bioactive constituents of *C. dactylon* is both relevant and timely. Therefore, the present study aims to isolate, characterise, and evaluate the flavonoid constituents of *C. dactylon*, with specific emphasis on their potential biological activities. By elucidating the molecular basis of these properties, this work seeks to contribute to the growing body of evidence supporting the therapeutic value of medicinal plants and to provide a scientific foundation for future applications of *C. dactylon* in health and disease management (Nasiri et al., 2012; Wu, 2011).

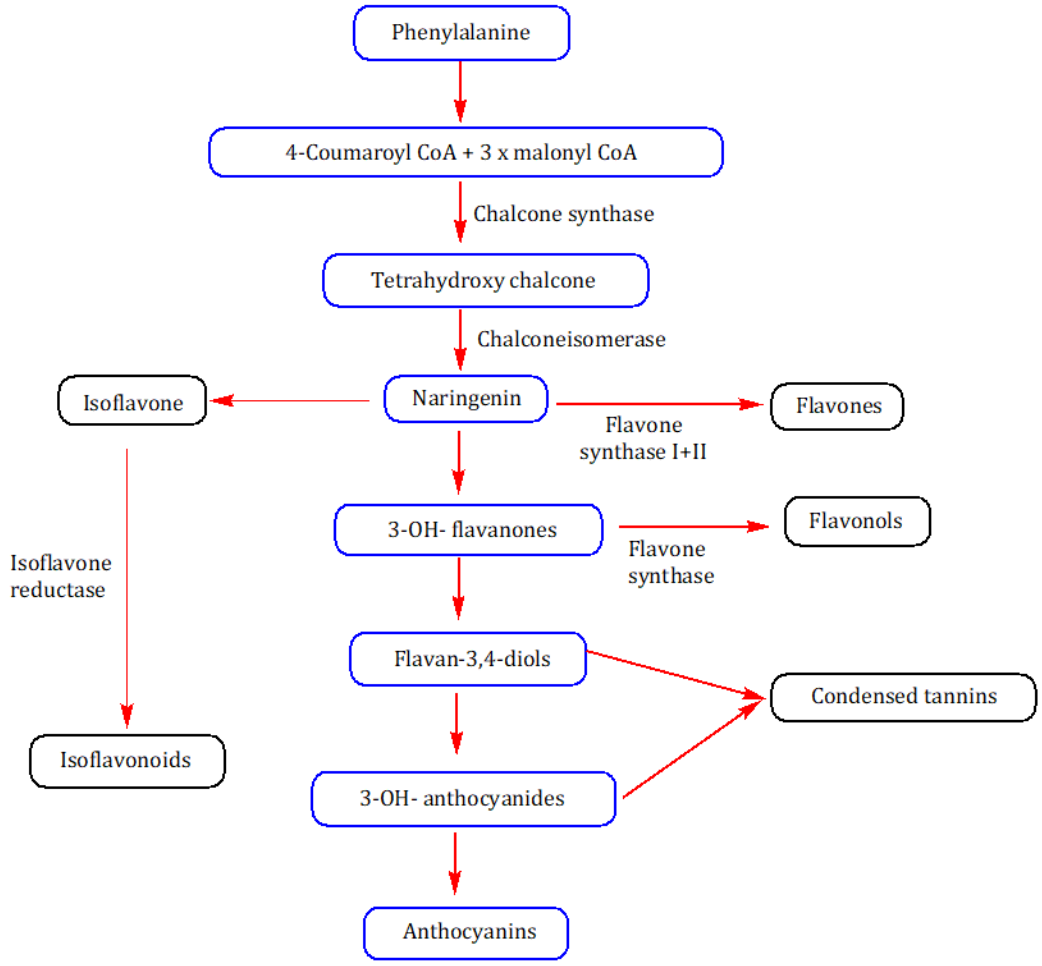

Fig. 1. Schematic overview of general flavonoid biosynthetic and transformation pathways relevant to higher plants, including *Cynodon dactylon* .

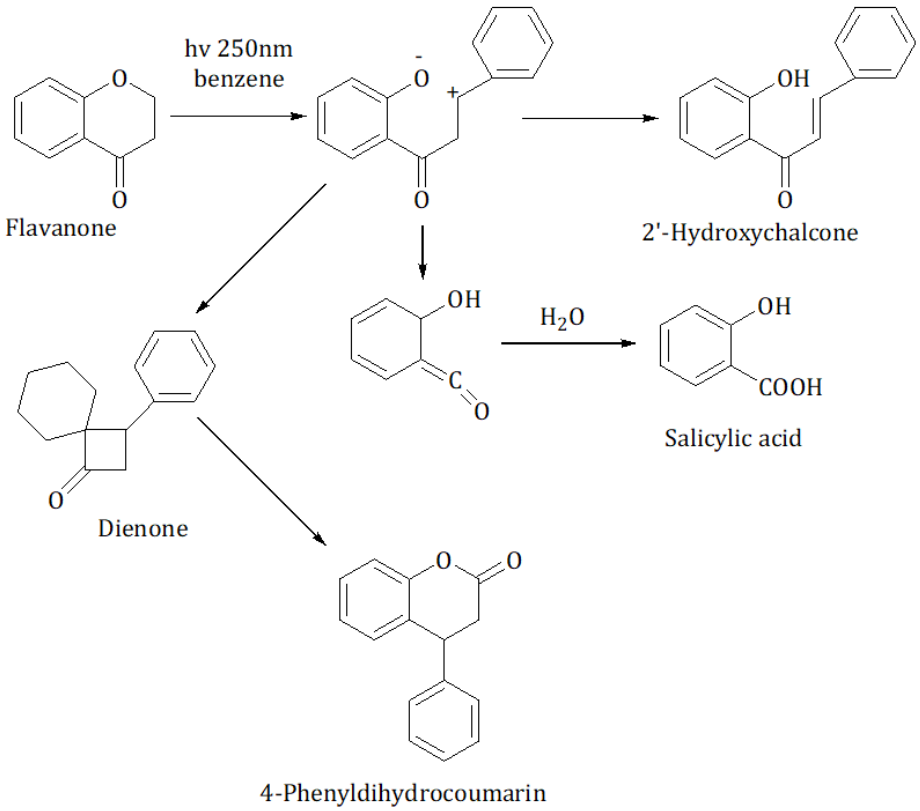

Fig. 2. Phenolic acid biosynthetic pathway in plants

Fig. 3. *Cynodon dactylon* (L.) Pers. (Bermuda grass)

Table 1. Taxonomic classification

Taxonomic Rank	**: Classification**
Kingdom	: Plantae
Subkingdom	: Tracheobionta
Superdivision	: Spermatophyta
Division	: Magnoliophyta
Class	: Liliopsida
Subclass	: Commelinidae
Order	: Cyperales
Family	: Poaceae
Genus	: *Cynodon*
Species	: *C. dactylon*

2. Literature review

This review presents a narrative synthesis of published research on the phytochemical profile and pharmacological activities of *Cynodon dactylon* (L.) Pers. Relevant literature was identified from PubMed, Scopus, ScienceDirect, Google Scholar, and key reference lists, covering studies published between 1990 and 2025. Included works comprise original research, experimental studies, and selected reviews reporting *in vitro*, *in vivo*, and limited clinical findings.

Because of substantial heterogeneity in plant material, extraction methods, study models, and outcome measures, formal systematic comparison or meta-analysis was not feasible. Instead, studies were descriptively evaluated based on relevance to phytochemical characterisation, biological activity, and translational significance. Key focus areas included antioxidant, anticancer, antidiabetic, anti-inflammatory, immunomodulatory, antimicrobial, wound-healing, angiogenic, and antiviral properties.

This narrative approach integrates evidence from classical pharmacological screening through to recent mechanistic and formulation-based studies, highlighting recurring biological patterns and existing research gaps while avoiding overstating clinical readiness.

2.1. Anticancer activity

Salahuddin *et al.* Bioactive plant compounds have gained significant attention for their tumour-suppressing properties in experimental carcinogenesis models. This study evaluated the *in vitro* anticancer activity of organic extracts of *C. dactylon* and *Oxalis corniculata* on the Hep2 cancer cell line, with normal human corneal epithelial cells (HCEC) as controls, using the MTT assay. Real-time PCR was used to assess p53 and PTEN gene expression in treated Hep2 cells, and DNA fragmentation assays were performed to detect extract-induced DNA damage. The ethanolic extract of *C. dactylon* and the methanolic extract of *Oxalis corniculata* showed IC50 values of 0.042 mg/mL (49.48% cell death) and 0.048 mg/mL (47.93% cell death), respectively, without toxicity to HCEC. Both extracts induced dose-dependent cytotoxicity comparable to the positive control. No significant changes in p53 or PTEN expression were observed, and DNA fragmentation was absent. These findings suggest that the extracts contain anticancer components that warrant further isolation and characterisation for potential therapeutic use (Salahuddin et al., 2016).

Baskar *et al.* examined the antioxidant, antiproliferative, and programmed cell death capabilities of plants in the 1,1-diphenyl-2-pyrazyl (DPPH) and nitric oxide radical scavenger (NO) tests and in the normal (VERO) and tumour (COLO) cell lines (COLO320DM, MCH-7, AGS, A549). *In vivo*, the efficacy of the methanolic extract of *C. dactylon* in reducing colon carcinogenesis in DMH-induced albino rats was demonstrated (Baskar & Ignacimuthu, 2010).

Khlifi *et al.* obtained a significant amount of the substance *C. dactylon, which* was extracted using a process involving petroleum ether, dichloromethane, acetone, methanol, and water (3.1). Phenolics (6.9 g of gallic acid equivalents/kg of dry matter), tannins (2.32 g of catechin equivalents/kg of dry matter), and flavonoids (0.9 g of catechin equivalents/kg of dry matter) were also evaluated. The extracts have been tested for antioxidant, antimalarial, and anticancer properties. The most active substance was water (IC50 = 57.21 ± 1.47 mg/L), followed by acetone extract (IC50 = 38.9 mg/L) and petroleum ether extract (IC50 = 39.9 mg/L). The amount of anthracyanin is well correlated with the effectiveness of the antimalarial drug (R_2 = 0.79 and 0.78). The LC–MS analysis of the extracts having the good activities anticancer and antimalarial, has revealed the presence of seven anthocyanins (delphinidin-3-O-acetylglucoside, petunidin-3-O-caffeoylglucoside-5-O-glucoside, petunidin-3-O-coumarylglucoside-5-O-glucoside, malvidin-3-O-monoglucoside, delphinidin-3-O-acetylglucoside-pyruvic acid, petunidin-3-O-acetylglucoside-5-O-glucoside and cyanidin-3,5-O-diglucoside) identified for the first time in this plant (Khlifi et al., 2013).

2.2. Antioxidant activity

Kowsalya *et al.* reported that *C. dactylon* protected Swiss albino mice against diethyl nitrosamine (DEN)–induced hepatocarcinoma. Mice received 50 mg/kg of the plant methanolic extract weekly for 30 days following DEN administration. The study demonstrated significant increases in antioxidant enzymes, including CAT, GPx, and GST, in both blood and liver tissue. Levels of liver marker enzymes AST and ALT were also reduced, indicating hepatoprotection. Overall, the findings suggest that *C. dactylon* root extract mitigates DEN-induced hepatocarcinoma by enhancing endogenous antioxidant defences and reducing serum aminotransferase levels (Kowsalya et al., 2015).

Mozafari *et al.* used five drying methods for testing of *C. dactylon* leaf and rhizome phytochemical content and antioxidant potential: shade drying (SHD), solar drying (SOD), and oven drying at 30 °C (OD30), 40 °C (OD40), and 50 °C (OD50). OD50 dried rhizome and leaf in 18.3 and 12 h, respectively, faster than SHD and SOD. GC-MS analysis detected 15 elements in leaf extracts and 17 in rhizome extracts, representing 99% of all components. After drying, the primary ingredients were fatty acids (palmitic acid, linoleic acid, ethyl palmitate, ethyl linoleate, ethyl oleate), their methyl esters (ethyl palmitate, ethyl linoleate, ethyl oleate), and derivatives (dihomo-γ-linoleic acid High drying temperatures affected *C. dactylon* phytochemicals such as 5-hydroxymethylfurfural and ethyl linoleate. Higher drying temperatures also produce or increase 2,3-dihydrobenzofuran, tricyclopentadeca-3,7-dien, 2,3-dihydro-3,5-dihydroxy-6-methyl-4H-pyran-4-one, and diacetin. The 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical scavenging experiment showed that oven-dried rhizomes had higher IC50 values (significance level of 0.05) than shade-dried leaves and rhizomes at 400 mg/mL to quench more than 84% of DPPH (IC50 59.12 µg/mL). We found that OD30 is a versatile drying method that preserves the phytochemicals and antioxidant activity of *C. dactylon* while reducing drying time (Mozafari et al., 2018).

Roy *et al.* extracted datura seed, fruit pulp, and durva aerial components using Soxhlet and cold extraction with methanol and distilled water. TPC and TFC were measured using standard procedures. An *in vitro* cytotoxicity experiment was done in the Vero cell line using 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide. The extract was tested for antioxidant activity using 2,2-diphenyl-1-picrylhydrazyl radical scavenging. The Soxhlation-prepared methanolic extract of *C. dactylon* exhibits vigorous free radical scavenging activity, with an IC50 value of 100 µg/mL. A methanolic cold extract of datura fruit had a Vero cell line IC50 of 3.0 mg/mL. We found vigorous antioxidant activity in *C. dactylon* and *D. metel* plant sections (Roy et al., 2016).

Collectively, current evidence suggests that the antioxidant and anti-inflammatory mechanisms of *C. dactylon* are mediated through both direct radical-scavenging activity and indirect regulation of cytokine and stress-response pathways. However, further mechanistic studies using targeted molecular analyses are required to confirm these signalling relationships *in vivo*.

2.3. Anti-arthritic activity

Sindhu *et al.* examined *C. dactylon's* preventive efficacy against adjuvant-induced arthritis in rats. Intradermal injection of full Freund's adjuvant into the right hind paw caused arthritis. Inflammatory mediators, myeloperoxidase, nitrite, CRP, and

ceruloplasmin increased significantly. Oxidative stress was linked to a decrease in catalase, superoxide dismutase, glutathione peroxidase, vitamins C and E, and lipid peroxidation, as evidenced by greater thiobarbituric acid reactive compounds. *C. dactylon* (20mg/kg/b.wt) orally given to arthritic rats after adjuvant injection significantly reduced inflammatory response, oxidative stress, and arthritic alterations to near normal. The study suggests that *C. dactylon* extract may offer protection against arthritis (Sindhu et al., 2009).

Bhangale *et al.* stated that *C. dactylon* (L.) (Poaceae) is a traditional plant for treating fevers, skin problems, and rheumatic conditions. The ethanolic extract of *C. dactylon* was safe at all dose levels (100, 200, 400 mg/kg, orally), with no mortality up to 5000 mg/kg. In rats, *C. dactylon* demonstrated considerable antiarthritic efficacy against Freund's full adjuvant-induced arthritis. *C. dactylon* treatment significantly reduced paw percentage change, ankle diameter, clinical severity, and raised body weight. Biochemical measurements revealed considerable improvements in Hb and RBC levels in rats treated with *C. dactylon*. Treatment with *C. dactylon* dramatically reduced elevated levels of WBC, ESR, CRP, and TNFα in rats. *C. dactylon* has been shown to prevent arthritic joints by improving bone lesions, not cartilage lesions. Ethanolic extract of *C. dactylon* at 400 mg/kg results in improved haematological levels, CRP, and TNFα reduction (Bhangale & Acharya, 2014).

2.4. Anti-diabetic activity

Wang *et al.* investigated the whole herb of *C. dactylon*, which yielded Cysestermerol A, a rare and novel stilbene sestertermer. High-resolution electrospray ionisation mass spectrometry (HRESIMS), one- and two-dimensional NMR analyses, and electronic circular dichroism calculations were used to determine the planar structure, relative stereochemistry, and absolute configuration of Compound 1 (Cysestermerol A). This compound increased glucose uptake in HepG2 cells compared to the positive control, rosiglitazone, and significantly inhibited the *in vitro* activity of α-glucosidase (Wang et al., 2021).

Singh *et al.* investigated the effects of a single. They repeated oral administration of the aqueous extract of *C. dactylon* (family: Poaceae) on hypoglycaemic and antidiabetic activity in normal and streptozotocin-induced diabetic rats. The study also assessed the impact of repeated treatment on lipid profiles. Doses of 250, 500, and 1000 mg/kg were tested, with 500 mg/kg demonstrating the most significant therapeutic effect. In normal rats, blood glucose levels decreased by 31% four hours after treatment. In mildly diabetic rats, the glucose tolerance test showed a 23% reduction in blood glucose one hour after administering 500 mg/kg an effect comparable to tolbutamide (250 mg/kg). In severely diabetic rats, daily administration of 500 mg/kg for 14 days resulted in a 59% reduction in fasting blood glucose, along with reduced urine sugar and prevention of abnormal weight gain. Regarding lipid parameters, severely diabetic rats treated with 500 mg/kg of the extract exhibited significant improvements: total cholesterol (TC) decreased by 35%, LDL by 77%, and triglycerides (TG) by 29%, while HDL increased by 18%. These findings indicate that the aqueous extract of *C. dactylon* possesses potent antidiabetic activity, with notable hypoglycaemic and hypolipidemic effects (Singh et al., 2007).

Rahman *et al.* tested the ethanol extract of *C. dactylon* Pers. aerial parts (EECA) for antidiabetic and antidiarrhoeal properties in Wistar rats. In order to assess the antidiabetic efficacy of EECA, we used the OGTT and AIDT models. EECA was administered at 2 g/kg body weight in the OGTT and 1.5 g/kg in the AIDT models for the evaluation of antidiarrhoeal effects at doses of 1 g/kg and 750 mg/kg. A castor oil diarrhoea model and a barium sulphate milk gastrointestinal motility test were used. In Wistar rats, EECA doses of 2 g/kg in the OGTT and 1.5 g/kg in the AIDT significantly reduced blood glucose levels ($P<0.01$), suggesting an antidiabetic effect. EECA at a dose of 1 g/kg demonstrated significant ($P<0.05$) antidiarrhoeal efficacy in the castor oil paradigm. Significant findings ($P<0.05$) were observed in a barium sulfate milk model using identical animals (Rahman et al., 2015).

2.5. Immunomodulator activity

Kaleeswaran *et al.* examine the immunostimulatory effects of *C. dactylon* (L) ethanolic extract as a feed supplement. *C. catla* received 0% (Control), 0.05% (group I), 0.5% (group II), and 5% (group III) extract for 60 days. Non-specific humoral (lysozyme activity, antiprotease activity, and haemolytic complement) and cellular (reactive oxygen and nitrogen species, myeloperoxidase activity) immune responses were studied using blood samples every 10 days up to 60 days. The study found that feeding *C. dactylon* ethanolic extract significantly ($P < 0.05$) improved most non-specific immunological measures. Group III showed significantly higher non-specific immunity among experimental diet groups (5%). Control and plant extract-treated fish were tested for Aeromonas hydrophila disease resistance for 7, 14, 21, and 28 days. The extract concentration directly affected the relative percent survival rate (RPS) in treated samples. The spleen was also tested for Matrix Metalloproteinase (MMPs) by electron microscopy and gelatin zymography at 7 and 28 days of feeding. *C. dactylon* mixed diet slowed lymphocyte degradation and improved ultrastructure. MMP expression was lower in experimental diet groups than in controls, indicating A. hydrophila infection-induced stress. Numerous experiments demonstrate that *C. dactylon* ethanolic extract boosts Catla fish immunity (Kaleeswaran et al., 2011).

Mangathayaru *et al.* stated that oral administration of the juice at 250 and 500 mg/kg in balb/c mice improved humoral antibody response to antigen challenge, as shown by a dose-dependent, statistically significant increase in haemagglutination antibody and plaque-forming cell test titers. Conclusions: The fresh juice of *C. dactylon* has DNA-protective and immunomodulatory properties, supporting its usage as a 'rasayana' in Ayurvedic medicine (Mangathayaru et al., 2009).

Balasubramanian *et al.'s* study shows that the *C. dactylon* plant extract demonstrated vigorous anti-WSSV activity in both *in vivo* and *in vitro* methods. Immunological parameters, including proPO, O2−, NO, THC, and clotting time, were significantly ($P < 0.05$) higher in WSSV-infected shrimp treated with plant extract compared to control groups. *In vivo* and *in vitro* treatment of the *C. dactylon* plant extract significantly improves shrimp immunity. Oral administration of *C. dactylon* plant extract with pellet feed may prevent WSSV infection in shrimp, based on current findings and low-cost benefits (Balasubramanian et al., 2008).

2.6. Anti-allergic activity

Sánchez *et al.* evaluated two diagnostic preparations with Cyn d proteins from rural and urban environments. We conducted skin prick tests (SPT), nasal challenge tests (NCT), and eosinophil counts in nasal mucus in three groups: healthy participants, rhinitis with (+) Cyn d, and rhinitis with (-) Cyn d. SPT positive and negative results matched the two extracts 97% of the time. However, Cyn d-urban extract resulted in larger wheals ($P = .03$), and more rhinitis patients showed positive NCT ($n = 7$ vs 14, $P = .04$). Eosinophils in mucus increased significantly in positive NCT patients, but the extracts did not vary. The extracts in the skin and nasal tests did not affect healthy controls. The study indicates that urban *C. dactylon* growth circumstances can alter protein extract, potentially affecting allergic rhinitis patients (Sánchez et al., 2018).

Matthiesen *et al.* isolated Cyn d I, an allergen from *Bermuda grass* pollen, using concanavalin A-Sepharose affinity and carboxymethyl-

Sepharose chromatography. The allergen is the primary allergen in the pollen extract, according to immunoelectrophoretic methods, sodium dodecyl sulfate-polyacrylamide gel electrophoresis, IgE-inhibition, and skin testing. Sodium dodecyl sulfate-polyacrylamide gel electrophoresis shows Cyn d I as a prominent 32 kDa band and a minor 29 kDa band, both binding IgE. Both bands are detected by monospecific rabbit antibodies (Abs) against Cyn d I. The Abs' poor precipitation of allergens from other grass species suggests that Cyn d I has distinct immunochemical characteristics. Two out of four pure murine monoclonal Abs against Cyn d I bind to both bands, suggesting they are isoallergens with somewhat differing immunochemical characteristics. The four monoclonal Abs react with pollen from various grass species, particularly Poa pratensis and Dactylis glomerata. The NH2-terminal region, including 10% of the whole sequence, showed substantial similarity to Lol p I, the primary allergen of Lolium perenne. The amino acid composition and immunoelectrophoretic comparison revealed that the source whole-pollen extract contains approximately 75% wt/wt of Cyn d I (Matthiesen et al., 1991).

Chang *et al.* examined isoforms using two-dimensional gel electrophoresis. The antigenic differences between isoforms were assessed using monoclonal antibodies and radioimmunoprecipitation (MAbs). MAb-affinity chromatography was used to separate the acidic, basic, and neutral isoforms for RAST and competitive RAST. In addition, microsequencing examined the N-terminal sequence. The Cyn d I protein had 11 isoforms in extracts from several Bermuda grass pollen sources (BGP). They were classified as acidic (Cyn d I-A, B, C, D, E, F, G, H, and I), neutral (I-X), or basic (I-J). The pollen preparations consistently included Cyn d I-G, with an isoelectric point of 6.4, while the basic Cyn d I-J concentration ranged from less than 5% to over 20%. The basic and neutral isoforms have marginally lower molecular weights than the acidic ones. Every isoform has a common antigenic determinant detectable by MAb 4-37, while the basic and neutral isoforms have a unique one recognisable by MAb 1-61. Both acidic and basic/neutral Cyn d I were detected by human IgE in BGP-allergic patient sera, according to RAST. Competitive RAST demonstrated strong acidic-basic-neutral isoform crossreactivity. The N-terminal 20 amino acid residues of basic Cyn d I-J and the prevalent acidic isoform Cyn d I-G shared 95% sequence similarity. This investigation found that basic Cyn d I-J is a significant allergen, with varying levels in various batches of BGP (Chang et al., 1995).

2.7. Anti-microbial/antibacterial activity

Marasini*et al.* stated that *C. dactylon* moderately inhibited 13 bacterial species, including methicillin-resistant Staphylococcus aureus, imipenem-resistant Pseudomonas aeruginosa, multidrug-resistant Salmonella typhi, and S. typhimurium. The investigated ethanolic extracts have MIC values ranging from 31 to >25,000 µg/mL. Ethanolic extracts of Cinnamomum camphora, Curculigo orchioides, and Curcuma longa showed the highest antibacterial activity against S. pyogenes (MIC: 49, 49, and 195 µg/mL), while the chloroform fraction of *C. dactylon* showed the best activity against S. aureus (MIC: 31 µg/mL). The plant extracts of *C. dactylon, C. camphora, C. orchioides, and C. longa* showed potential antibacterial action (MIC < 100 µg/mL) (Marasini et al., 2015).

Nischitha *et al.* reported that although *C. dactylon* (L.) Pers. is valued for its therapeutic uses; its endophytic fungi and their metabolites remain poorly explored. Their study isolated diverse endophytic fungi from culm, leaf, and inflorescence tissues using moist blotter (MB), PDA, and MEA media, with PDA followed by MEA yielding the highest species richness, diversity, and evenness. Among the four tested species, *Curvularia tsudae* was selected for antibacterial and antioxidant assays. Ethyl acetate and methanol extracts of its mycelial mat (MM) and culture filtrate (CF) were evaluated. The ethyl acetate CF extract showed moderate antibacterial effects against *Enterococcus faecalis*, *E. coli*, *Pseudomonas fluorescens*, and *Staphylococcus aureus*. In contrast, the methanolic extract displayed high to moderate antifungal activity against *Aspergillus flavus*, *A. niger*, and *Fusarium*. Cyclic voltammetry indicated vigorous antioxidant activity; HPLC confirmed coumarins, and Orbitrap LC–MS revealed multiple bioactive compounds. The findings highlight *C. tsudae* as a promising pharmaceutical resource (Nischitha et al., 2020).

Sahu *et al.* reported synthesising silver nanoparticles (Ag-NPs) by reducing Ag+ ions in aqueous/organic plant extracts; however, they are sluggish. Silver nanoparticles were promptly produced from aqueous silver nitrate utilising *C. dactylon* leaf extract as a reducing agent and sunlight as a catalyst. Gradual colour and pH changes and ultraviolet–visible spectroscopy verified Ag-NP production. Ag-NPs have a 451 nm surface plasmon resonance. A reduction in pH suggests a plausible mechanism for Ag-NP production using hydroxyl (OH−) ions from leaf extract polyphenols. X-ray diffraction revealed crystal lattices in Ag-NPs. Transmission electron microscopy showed polydispersed 8–10-nm Ag-NPs, while scanning electron microscopy showed spherical Ag-NPs. The produced Ag-NPs showed antibacterial efficacy against *Escherichia coli, Pseudomonas aeruginosa, Staphylococcus aureus, and Salmonella typhimurium* (Sahu et al., 2013).

2.8. Treatment of stress-induced infertility

Chidrawar *et al.* studied Indian mythology where *C. dactylon* (Family: Poaceae) is offered to Lord Ganesha as a tackler. Even on wasteland, roadsides, and dry regions, it spreads rapidly on cultivated land. This study tested whether this plant's elements can soothe sexual stress. In this study, immobilisation stress caused male infertility, and *C. dactylon* restored it by examining sexual behaviour, performance, seminal vesicle fructose, epididymal sperm concentration, and histopathology. Methanolic extract of *C. dactylon* improved stress-induced sexual dysfunction, sexual performance, fructose content, sperm concentration, accessory sexual organs, and body weight in rats. Conclusion: *C. dactylon* methanolic extract contains active components with potent aphrodisiac and male fertility properties (Chidrawar et al., 2011).

Garza *et al.'s* study employed 30 60-day-old Wistar male rats weighing 280–300 g. Animal age was chosen based on rat reproductive cycle development. The following groups received extracts suspended in distilled water and orally delivered daily with a stomach probe for 36 days. A pilot test determined the efficacious dosage, which was 50 mg/kg for all extracts. Animals were divided into five groups: Control group (n=6), untreated; The following groups were treated with 50 mg/kg extracts of T. lucida, *C. dactylon*, L. graveolens HBK, and Ficus-indica (Garza et al., 2015).

2.9. Anti-chikungunya activity

Murali *et al.* stated that the anti-chikungunya virus (CHIKV) fraction was obtained from *C. dactylon* ethanolic extract using silica gel column chromatography. The fraction's principal phytochemicals were identified utilising phytochemical standards in reverse phase-HPLC and GC-MS experiments. The fraction's cytotoxicity and CHIKV-fighting capabilities were tested in Vero cells. After fraction treatment of virally infected Vero cells, RT-PCR was used to measure viral replication reduction. The anti-CHIKV ethanolic fraction of *C. dactylon* contained flavonoids, luteolin, and apigenin, according to reverse-phase HPLC and GC-MS investigations. Approximately 98% of the fraction showed vigorous viral inhibitory activity at 50 µg/mL, as measured by reduced cytopathic impact. The cytotoxic concentration was 250 µg/mL. RT-PCR analysis revealed a significant decrease in viral mRNA synthesis in fraction-treated infected cells compared to control cells (Murali et al., 2015).

2.10. Wound healing potential

Biswas *et al.* detect phytochemicals in plant aqueous extract by using HPLC. The extract was tested for acute and dermatological toxicity. The effects of 15% ointment (w/w) of the extract compared to placebo and framycetin on full-thickness punch wounds in Wistar rats were assessed using wound contraction size (mm^2), tensile strength (g), tissue DNA, RNA, protein, hydroxyproline, and histological inspection. The ointment was applied to selected chronic and complex wounds and evaluated for efficacy using granulation, epithelialisation, vascularity, and routine haematological tests. Significant outcomes ($p<0.05$) were obtained in both clinical and pharmacological tests. This study examines *C. dactylon* aqueous extract's wound-healing ability in animal models and humans. The anti-oxidative action of phenolic acids and flavonoids in *C. dactylon* aids in wound healing and collagen production (Biswas et al., 2017).

Perumal *et al.* studied these studies, which provided evidence for the efficacy of the CSCE scaffold in the treatment of wounds, as demonstrated in *in vivo* wound healing experiments using full-thickness excision wounds in the Wistar rat model. Compared to wounds treated with Col and CS scaffolds, those treated with CSCE scaffold exhibited accelerated healing and increased collagen deposition (Perumal et al., 2018).

Rallos *et al.*'s study used a randomised controlled trial to test Bermuda grass (*C. dactylon*) topical cream on male albino mice with second-degree burns. Study participants were randomly allocated to three groups of six mice. Silver sulfadiazine was administered to Group 1, base cream to Group 2, and 5% Bermuda grass topical cream to Group 3. After the burn, all therapies were administered every 24 hours, and wound contraction was measured every 48 hours until full contraction was recorded on the 17th day. The study suggested Bermuda grass might replace Silver sulfadiazine in burn injury therapy. A greater mean wound contraction rate (93.14±4.59) was seen with 5% Bermuda grass topical cream compared to Silver sulfadiazine and Base cream (78.77±8.98 and 89.38±4.24, respectively) (Rallos et al., 2020).

2.11. Angiogenic activity

Soraya *et al.* administered carrageenan into an air-pouch on the rats' backs, and after an IV injection of carmine red dye on day 6, granulation tissue was processed for dye content measurement. VEGF expression in HUVECs was used to test the extract's angiogenicity *in vitro*. The extract, administered orally at 400 mg/kg/day, dramatically improved angiogenesis ($p < 0.05$) and considerably reduced neutrophil and total leukocyte infiltration (p

Table 2. Bioactive compounds, experimental models, and pharmacological activities of *Cynodon dactylon.*

Pharmacological Activity	Bioactive Compound (s) / Extract Type	Experimental Model	Key Findings	Ref.
Anticancer	Anthocyanins (delphinidin, malvidin, petunidin, cyanidin)	*In vitro* (Hep2, COLO, AGS, A549 cell lines)	LC–MS–identified anthocyanins showed dose-dependent cytotoxic and antiproliferative effects.	(Baskar & Ignacimuthu, 2010; Khlifi et al., 2013; Salahuddin et al., 2016)
Antioxidant	Apigenin, luteolin, orientin, vitexin (flavonoids)	*In vitro* (DPPH, NO assays); in vivo (DEN-induced mice)	Strong radical-scavenging activity; increased CAT, GPx, GST; hepatoprotection	(Kowsalya et al., 2015; Mozafari et al., 2018; Roy et al., 2016)
Anti-inflammatory / Anti-arthritic	Flavonoid-rich extracts (apigenin & luteolin derivatives)	*In vivo* (FCA-induced arthritis in rats)	Reduced TNF-α, CRP, paw swelling, and oxidative stress markers	(Bhangale & Acharya, 2014; Sindhu et al., 2009)
Anti-diabetic	Cysestermerol A; aqueous/ethanolic extracts	*In vitro* (HepG2 cells); in vivo (STZ-diabetic rats)	α-Glucosidase inhibition; enhanced glucose uptake; reduced fasting glucose & improved lipid profile	(Rahman et al., 2015; Singh et al., 2007; Wang et al., 2021)
Immunomodulatory	Polyphenol-rich extracts	*In vivo* (fish, mice, shrimp models)	Enhanced humoral & innate immune responses; increased survival against infections	(Balasubramanian et al., 2008; Kaleeswaran et al., 2011; Mangathayaru et al., 2009)
Anti-allergic	Cyn d I (major pollen allergen protein)	*In vitro*; human diagnostic studies	Identified and characterised major IgE-binding allergen and isoforms	(Chang et al., 1995; Matthiesen et al., 1991; Sánchez et al., 2018)
Antimicrobial	Curvularin, umbelliferone (endophytic fungal metabolites); plant extracts	*In vitro* (Gram-positive & Gram-negative bacteria)	Moderate to strong antibacterial activity (MIC as low as 31 µg/mL)	(Marasini et al., 2015; Nischitha et al., 2020; Sahu et al., 2013)
Stress-induced infertility	Methanolic extract (bioactive constituents not isolated)	*In vivo* (stress-induced male rat model)	Restored sperm count, sexual behaviour, and reproductive indices (marker-based outcomes)	(Chidrawar et al., 2011; Garza et al., 2015)
Anti-chikungunya	Luteolin, apigenin	*In vitro* (CHIKV-infected Vero cells)	~98% inhibition of viral replication at 50 µg/mL; reduced viral mRNA	(Murali et al., 2015)
Wound healing	Catechin, rutin, quercetin, apigenin, kaempferol	*In vivo* (rats, mice); pilot clinical use	Accelerated wound contraction, collagen synthesis, and tensile strength	(Biswas et al., 2017; Perumal et al., 2018; Rallos et al., 2020)
Angiogenic / Anti-atherosclerotic	Apigenin, luteolin, orientin, vitexin; ethanolic extract	*In vitro* (HUVECs); in vivo (rats)	Upregulated VEGF, enhanced angiogenesis, and reduced atherosclerotic lesions	(Pashaie et al., 2017; Soraya et al., 2015)

< 0.001) in granulation tissues. Additionally, the extract at 100 µL/mL boosted total VEGF expression in HUVECs. This study found that *C. dactylon* aqueous extract stimulates VEGF expression and angiogenesis (Soraya et al., 2015).

Belal Pashaie et al. stated that 36 male Wistar rats were divided into six groups. The control group got normal food, the sham group had a high cholesterol diet (HCD; 1.50% cholesterol, 24% fat), and other groups received HCD and ethanolic extract of *C. dactylon* at low (100 mg kg-1), moderate (200 mg kg^{-1}), and maximal (400 mg kg^{-1}) dosages by gavage. The last group got HCD-gavaged atorvastatin (10 mg kg^{-1}). The trial lasted six months for all groups. Blood samples were tested for total cholesterol (TC), triglyceride (TG), LDL-C, and HDL-C after this time. Histopathological and immunohistochemical tests on the coronary and aorta arteries were also done. In the HCD group, vessel wall thickness and smooth muscle cell proliferation increased, but similar changes were not observed in *C. dactylon*-treated groups. Treatment of HCD mice with *C. dactylon* improved lipid profile by reducing TC, TG, and LDL-C. *C. dactylon* seems to inhibit early atherosclerotic alterations in vessel walls (Pashaie et al., 2017).

The numerous pharmacological activities of *C. dactylon* are demonstrated in this document (**Table 2** & **Fig. 4**).

The pharmacological activities summarised in this table are supported by evidence of differing strengths. Compound-level evidence refers to studies in which individual bioactive molecules were structurally characterised (e.g., by HPLC, LC–MS, NMR) and directly tested in biological assays. Extract-level evidence denotes activities observed using crude or fractionated plant extracts containing multiple constituents, where the specific active compound(s) were not fully isolated. Marker-based outcomes describe physiological or biochemical parameters (e.g., enzyme levels, sperm count, fructose concentration) that indicate biological effects but do not establish direct causality of a single compound. Clinical or human data, where present, are limited to diagnostic or pilot observations and should be interpreted cautiously.

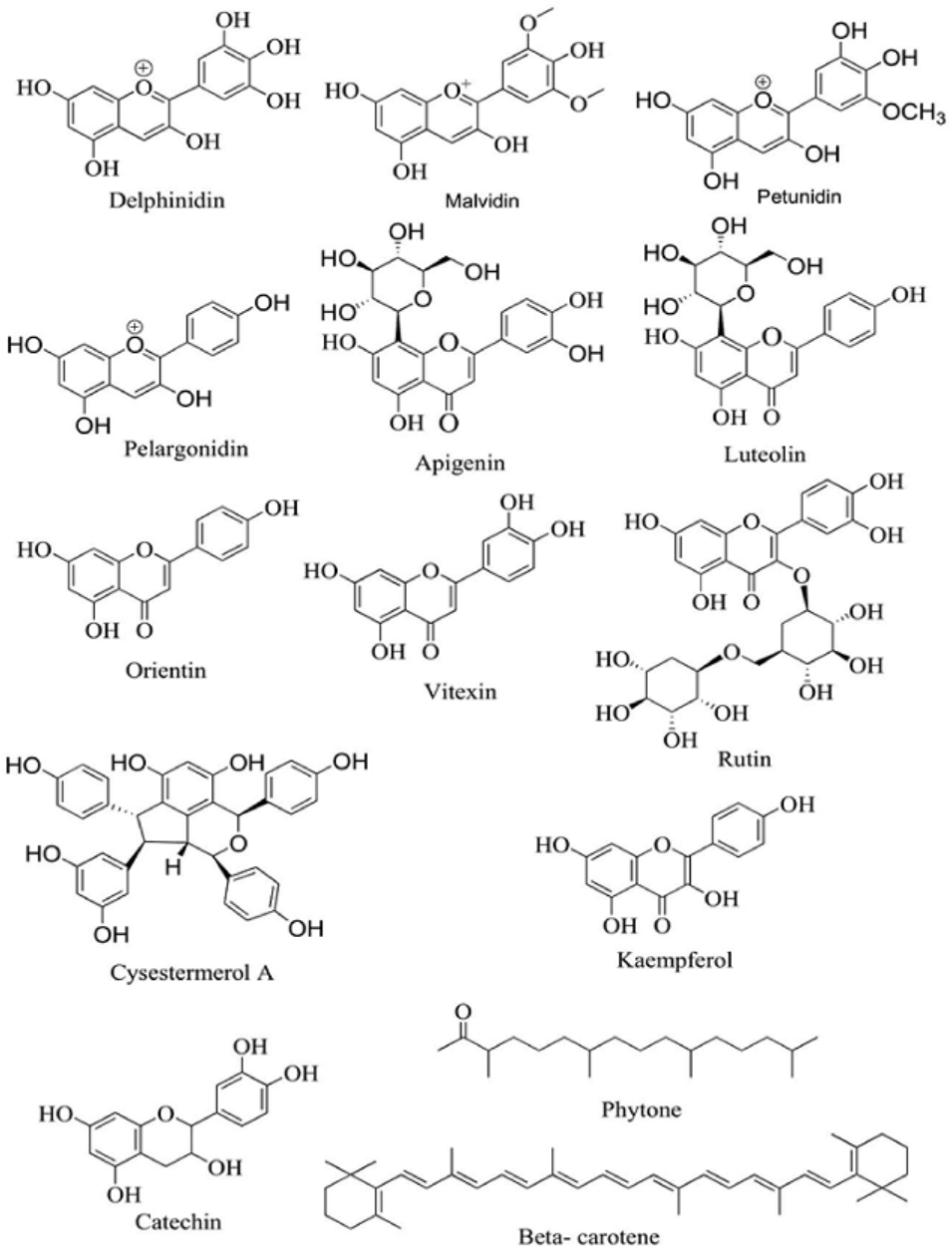

Fig. 4. Chemical structures of selected bioactive phytochemicals reported from *Cynodon dactylon.*

3. Discussion

The present review critically evaluates *Cynodon dactylon* (L.) Pers. as a pharmacologically versatile yet translationally underdeveloped medicinal plant, moving beyond descriptive ethnomedicinal reports toward a mechanistically informed framework (Shendye & Gurav, 2014; Singh et al., 2009). A major strength of the available literature is the consistent demonstration of antioxidant, antidiabetic, anti-inflammatory, wound-healing, and angiogenic activities across independent *in vitro* and *in vivo* studies (Baskar & Ignacimuthu, 2010; Bhangale & Acharya, 2014; Biswas et al., 2017; Khlifi et al., 2013; Kowsalya et al., 2015; Pashaie et al., 2017; Perumal et al., 2018; Rallos et al., 2020; Sindhu et al., 2009; Singh et al., 2007; Soraya et al., 2015; Wang et al., 2021). The use of advanced analytical techniques, particularly HPLC and LC–MS, has improved phytochemical characterisation and resolved earlier inconsistencies by confirming the presence of key flavonoids, including apigenin, luteolin, orientin, and vitexin (Baskar & Ignacimuthu, 2010; Harlan, 1970; Khlifi et al., 2013; Muthukrishnan et al., 2015). Several studies have also progressed beyond general biological screening by identifying convergent molecular targets, such as α-glucosidase inhibition, regulation of antioxidant enzymes, suppression of inflammatory mediators, and VEGF-mediated angiogenic signalling (Bhangale & Acharya, 2014; Khlifi et al., 2013; Soraya et al., 2015; Wang et al., 2021).

Despite these strengths, the overall quality of evidence remains limited by methodological constraints. Most animal studies involve small sample sizes (commonly n = 6–8 per group), short treatment durations, and limited dose–response evaluation, which restricts statistical power and reproducibility. *In vitro* investigations frequently rely on single cell lines and cytotoxicity-based assays with minimal mechanistic validation. Consequently, many reported pharmacological effects should be interpreted as exploratory rather than definitive (Garza et al., 2015; Salahuddin et al., 2016).

Contradictory findings in the literature particularly regarding phytochemical composition and antioxidant potency are largely attributable to variability in plant parts, extraction solvents, drying methods, and processing conditions rather than true biological inconsistency. These factors highlight the lack of extract standardisation and complicate cross-study comparisons. In addition, immunomodulatory data derived from fish and shrimp models primarily reflect innate immune activation and should be regarded as preliminary screening evidence rather than predictors of human immune responses (Kaleeswaran et al., 2011; Mangathayaru et al., 2009; Singh et al., 2007).

Clinical evidence for *C. dactylon* remains scarce. Apart from limited pilot or diagnostic studies, no well-powered randomised controlled trials have been conducted. Toxicological evaluation is also insufficient, as most studies report only short-term safety and do not address chronic toxicity, genotoxicity, reproductive toxicity, or herb–drug interactions (Chidrawar et al., 2011; Murali et al., 2015; Sindhu et al., 2009). These gaps represent major barriers to regulatory approval and clinical translation.

Overall, while *C. dactylon* exhibits consistent and biologically plausible pharmacological activity; the current evidence base is dominated by preclinical and methodologically heterogeneous studies. Future research should prioritise standardised extract preparation, adequately powered experimental designs, comprehensive toxicological profiling, and rigorously designed human clinical trials to establish therapeutic efficacy and safety.

4. Conclusion

This review indicates that *Cynodon dactylon* (L.) Pers. is a pharmacologically promising yet translationally underdeveloped medicinal plant, with the current evidence base derived predominantly from *in vitro* and animal studies. Preclinical data suggest multi-target biological activity involving modulation of oxidative stress, inflammatory signalling, metabolic regulation, immune-related responses, and angiogenic pathways. Rather than asserting therapeutic efficacy, the present review emphasises mechanistic plausibility and identifies the principal barriers limiting clinical translation.

At present, research on *C. dactylon* remains confined to preclinical experimentation. The lack of analytically standardised extracts, limited pharmacokinetic and bioavailability information, insufficient toxicological characterisation, and the absence of well-designed and adequately powered human clinical trials collectively preclude definitive conclusions regarding clinical utility. Although formulation-based strategies, including nanotechnology-assisted delivery systems and biomaterial scaffolds, show experimental promise, these approaches remain at an early developmental stage, and no clinically approved or late-stage therapeutic products derived from *C. dactylon* are currently available.

Overall, *C. dactylon* should be regarded as a biologically plausible but clinically unvalidated multi-target botanical candidate. Progress toward evidence-based application will require standardised preparation methods, rigorous mechanistic and toxicological evaluation, and carefully designed human clinical trials. Until such evidence becomes available, conclusions regarding therapeutic use must remain cautious and proportionate to the existing level of evidence.

CONFLICT OF INTEREST

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