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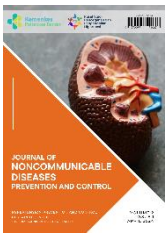

*Review Article*

# THE ANTIDIABETIC POTENTIAL OF *RUELLIA TUBEROSA* L.

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**ABSTRACT**

Diabetes mellitus (DM) is a metabolic condition characterized by insufficient insulin production or resistance to insulin, resulting in elevated blood sugar levels. Several synthetic medications, such as Acarbose, Metformin, Glibenclamide, Miglitol, and Voglibose, are presently employed to manage high blood sugar levels. However, these drugs have many side effects, causing some mild to severe adverse effects, including gastrointestinal symptoms, nausea, and vomiting. Hence, it is crucial to research natural products as promising antidiabetic alternatives. This study aimed to provide a comprehensive overview of the potential of *Ruellia tuberosa* L. as an antidiabetic drug candidate based on the secondary metabolite compounds contained in it. The literature review process involved searching specific keywords in various databases, including Google Scholar, the GARUDA portal, ScienceDirect, PubMed, and DOAJ. All incomplete, duplicates, and pay-access articles were filtered out, and inclusion criteria were applied. The result of this study shows that *Ruellia tuberosa* L. secondary metabolite compounds are alkaloids, amino acids, ascorbic acids, carbohydrates, flavonoids, glycosides, phenolics, quinoline, saponins, steroids, sterols, tannins, and terpenoids. *In silico* molecular docking analysis and *in vivo* testing of *Ruellia tuberosa* L. extract on streptozotocin (STZ)-induced diabetic Wistar rats show that *Ruellia tuberosa* L. has the potential to be developed as an antidiabetic alternative drug.

***Kata Kunci***
Antidiabetes
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*Ruellia tuberosa*

**ABSTRAK**

Diabetes mellitus (DM) adalah gangguan metabolik kronis akibat kekurangan insulin atau resistensi insulin yang menyebabkan kadar gula darah tetap tinggi secara abnormal. Terdapat banyak obat sintetis seperti Acarbose, Metformin, Glibenclamide, Miglitol, dan Voglibose yang saat ini digunakan untuk mengontrol hiperglikemia. Namun, obat-obatan tersebut memiliki banyak efek samping yang menyebabkan beberapa efek negatif ringan hingga parah, termasuk gejala gastrointestinal, mual, dan muntah. Oleh karena itu, penelitian terhadap bahan-bahan alami yang berpotensi sebagai alternatif antidiabetes menjadi sangat penting. Studi tinjauan pustaka ini bertujuan memberikan gambaran komprehensif tentang potensi pengembangan *Ruellia tuberosa* L. menjadi obat alternatif antidiabetes berdasarkan senyawa metabolit sekunder yang terkandung di dalamnya. Proses tinjauan literatur melibatkan pencarian dalam berbagai basis data termasuk Google Scholar, portal GARUDA, ScienceDirect, PubMed, dan DOAJ menggunakan kata kunci tertentu. Kemudian, artikel yang tidak lengkap, duplikasi, dan artikel yang berbayar dikecualikan, dan kriteria inklusi diterapkan. Hasil dari penelitian ini menunjukkan bahwa senyawa metabolit sekunder *Ruellia tuberosa* L. adalah alkaloid, asam amino, asam askorbat, karbohidrat, flavonoid, glikosida, fenolik, kuinolin, saponin, steroid, sterol, tanin, dan terpenoid. Analisis *docking* molekuler *in silico* dan uji *in vivo* ekstrak *Ruellia tuberosa* L. pada tikus Wistar yang diinduksi streptozotocin (STZ) menunjukkan bahwa ekstrak *Ruellia tuberosa* L. memiliki potensi untuk dikembangkan menjadi obat alternatif antidiabetes.



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## INTRODUCTION

Diabetes mellitus is a chronic metabolic disorder due to a lack of insulin or insulin resistance in which the blood sugar level remains abnormally high. Diabetes can cause various complications, both acute and chronic, if not adequately controlled (Debnath *et al*., 2020; Safitri *et al*., 2022). Diabetes mellitus is commonly classified into two types: type 1, or insulin-dependent, resulting from pancreatic damage impairing insulin production, and type 2, non-insulin-dependent, triggered by factors like obesity, aging, or environmental influences (Safitri, Sutrisno, *et al*., 2019).

Diabetes has become a global epidemic, with its prevalence steadily rising across the world. Type 2 diabetes accounts for 90% to 95% of all diabetes cases globally (Safitri, Srihardyastutie, *et al*., 2019; Safitri, Sutrisno, *et al*., 2019). The World Health Organization (WHO) projects that diabetes mellitus will impact around 366 million individuals globally by 2030, making it the seventh most common cause of death (Navik *et al*., 2022). WHO data shows that in 2019, diabetes mellitus was the third highest cause of death in Indonesia, with a rate of 39 deaths in males and 43 deaths in females per 100,000 population (WHO, 2024).

Various methods are employed to regulate blood sugar levels in diabetes, including reducing carbohydrate digestion, limiting glucose absorption, enhancing glucose uptake, inhibiting carbohydrate metabolism, and minimizing gluconeogenesis. Elevated post-meal blood glucose levels result from the absorption of dietary glucose, facilitated by metabolic enzymes in the gastrointestinal tract. Targeting the inhibition of these enzymes is a proven method for regulating high glucose levels in diabetes mellitus (Debnath *et al*., 2020; Mule & Naikwade, 2022). Numerous synthetic diabetic medications, such as Acarbose, Metformin, Glibenclamide, Miglitol, and Voglibose, are employed in managing high blood sugar levels. Miglitol and Voglibose work only on α-glucosidase, but Acarbose stops both α-amylase and α-glucosidase activities. However, these drugs have many side effects, causing some mild to severe adverse effects, including gastrointestinal symptoms, nausea, and vomiting. Because they have side effects, scientists are looking for new α-amylase and α-glucosidase inhibitors that come from natural sources. These should be less toxic, cause fewer or no side effects, and cost less to make than synthetic drugs. Hence, exploring natural compounds sourced from plants is crucial for uncovering potential treatments for diabetes (Debnath *et al*., 2020; Roosdiana *et al*., 2019; Safitri *et al*., 2022).

Indonesia possesses a wealth of diverse flora that serve as valuable reservoirs of raw materials for traditional medicines. Many countries widely recognize the beneficial uses of natural products like plants or flora (Safitri, Sutrisno, *et al*., 2019). *Ruellia tuberosa* L., a plant species from the Acanthaceae family, possesses numerous useful secondary metabolite compounds for various applications (Ciangherotti & Israel, 2022; Safitri, Fatchiyah, *et al*., 2020). Originally from Central America, this species now resides in numerous regions across tropical South and Southeast Asia, favoring grasslands and roadsides. Commonly growing as a weed in cultivated fields, it also inhabits xerophile and ruderal environments (Dutta *et al*., 2020). In Indonesia, this plant is locally known as pletekan or pletikan (Safitri, Roosdiana, *et al*., 2019; Safitri, Srihardyastutie, *et al*., 2019; Safitri, Sutrisno, *et al*., 2019).

A previous study looked at the leaf part of *Ruellia tuberosa* L. and found that it has different chemicals in it, such as phenols (0.36 mg/g), saponins (0.10 mg/g), glycosides (0.59 mg/g), flavonoids (0.75 mg/g), vitamins K and C, and carotenoids. Analysis of bioactive compounds in the root of *Ruellia tuberosa* L. using gas chromatography-mass spectrometry (GC-MS) identified 25 compounds, with notable percentages including stigmasterol (8.89%), sitosterol (3.99%), cholesterol (2.24%), and lupeol (68.14%). Triterpenoids, primarily lupeol, found in the root of *Ruellia tuberosa* L. possess significant antioxidant properties and are capable of reducing reactive oxygen species (ROS) levels (Roosdiana *et al*., 2019). *Ruellia tuberosa* L. harbors various active phytochemicals, such as flavonoids, phenolics, glycosides, steroids, triterpenoids, alkaloids, and tannins (Susilo & Farhan, 2023). Additionally, research on the secondary metabolite compounds found in the extract of *Ruellia tuberosa* L. demonstrated antidiabetic activity in living organisms, lowering blood glucose levels and malondialdehyde (MDA) levels, as well as improving the histopathological profiles of the kidneys of insulin-resistant rats.

In this study, we used information from several previous studies to look at the secondary metabolite compounds of *Ruellia tuberosa* L. We looked at how α-amylase and α-glucosidase from the human pancreas react with some compounds from *Ruellia tuberosa* L. extract. We also looked at how the extract of *Ruellia tuberosa* L. lowers blood glucose levels, MDA levels, and tumor necrosis factor-alpha (TNF-α) levels. This literature review aimed to provide a comprehensive overview of the potential for developing *Ruellia tuberosa* L. as an antidiabetic alternative drug based on the secondary metabolite compounds contained in it.

## MATERIALS AND METHODS

This study used a literature review research design. The objective of this research is to investigate the antidiabetic effect of *Ruellia tuberosa* L. Hence, inclusion criteria applied to the selection of articles include articles being intact, comprising primary research findings within the last five years, and investigating secondary metabolite compounds; in silico molecular docking analysis of the interaction between human

pancreatic α-amylase and α-glucosidase with the secondary metabolite compounds; or an in vivo experiment of *Ruellia tuberosa* L. to investigate its antidiabetic potential.

The study accessed articles through searching on various platforms, including Google Scholar, the GARUDA portal, ScienceDirect, PubMed, and DOAJ (Directory of Open Access Journals), utilizing a combination of keywords and connectors ("diabetes" OR "antidiabetic") AND ("kencana ungu" OR "*Ruellia tuberosa* L."), along with their variations.

Based on the predetermined keywords, a total of 537 articles were retrieved, with search results from Google Scholar totaling 486 articles, 24 articles from the GARUDA portal, 17 articles from ScienceDirect, 6 articles from PubMed, and 4 articles from DOAJ. Incomplete articles, duplications, and pay-access articles were excluded. Following the application of these exclusions, a total of 56 articles remained. Subsequently, further screening was conducted based on topic relevance and title selection, resulting in 28 articles. Then, based on the appropriateness of the research design, data completeness, and alignment with the study's literature review objectives, 9 articles were selected.

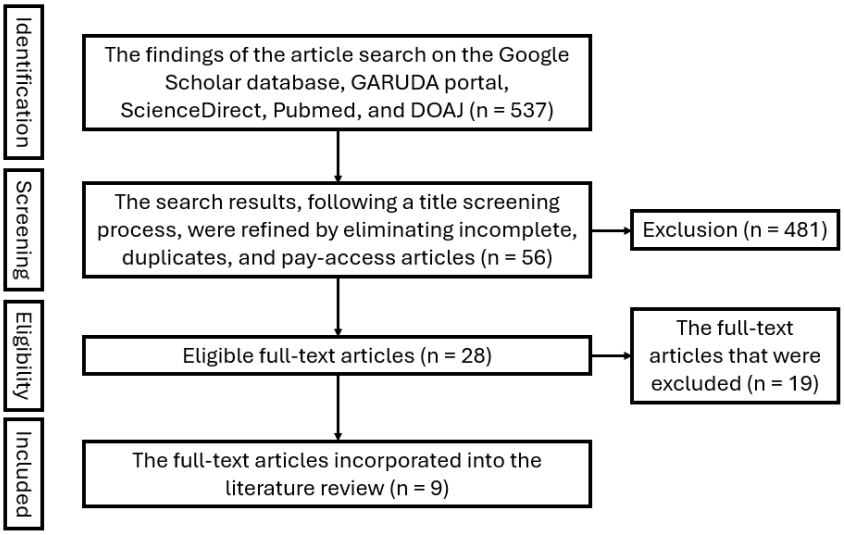


**Figure 1** The PRISMA flowchart outlined the process of selecting articles for the study

## RESULTS AND DISCUSSION

The literature review focused on 15 articles that were screened following the PRISMA protocol and based on their relevance to the study topic, consisting of 5 articles on secondary metabolite compounds detected in the extract of *Ruellia tuberosa* L.; 3 articles on the interaction of human α-amylase and human α-glucosidase with *Ruellia tuberosa* L. compounds by *in silico* molecular docking analysis; and 2 articles on *in-vivo* studies of the antidiabetic effects of the extract of *Ruellia tuberosa* L. on streptozotocin (STZ)-induced diabetic Wistar rats (*Rattus norvegicus*).

### Secondary Metabolites of *Ruellia tuberosa* L.

**Table 1** shows the phytochemicals content of *Ruellia tuberosa* L. extracts. Phytochemical analyses were performed by observing color alterations when extracts interacted with standard reagents for detecting secondary metabolites. Identifying the phytochemical components in these extracts is crucial as this information predicts the biological and pharmacological effects of the plants. In the phytochemical screening conducted by Dutta *et al*., (2020); Gokulakrishnan *et al*., (2023); Handayani *et al*., (2020); Harika & Radhika, (2021); Safitri, Fatchiyah, *et al*., (2020) have shown that different parts of *Ruellia tuberosa* L. extract including root, leaf, flower, seed, and tuber contain secondary metabolite compounds such as alkaloids, amino acids, ascorbic acids, carbohydrates, flavonoids, glycosides, phenolics, quinoline, saponins, steroids, sterols, tannins, and terpenoids. These findings indicate that *Ruellia tuberosa* L. possesses numerous secondary metabolites. Flavonoids, phenolic compounds, and ascorbic acids are well-known for their remarkable antioxidant abilities, while tannins, polyphenolic compounds, exhibit antimicrobial effects (Safitri, Fatchiyah, *et al*., 2020).

**Table 1** The phytochemical screening results of *Ruellia tuberosa* L. extracts

| | Extraction method | Plant's part | Secondary metabolites |
|---|---|---|---|
| Safitri, Fatchiyah, *et al.* (2020) | Maceration technique with distilled water | Root | Flavonoids, Phenolics, Ascorbic acids, Tannins |
| Handayani *et al.* (2020) | Maceration technique with ethanol | Leaf | Saponins, Tannins, Flavonoids, Alkaloids, Steroids |
| Harika & Radhika (2021) | Soxhlet extraction with ethanol | Tuber | Phenolics, Flavonoids, Terpenoids, Saponins, Carbohydrates, Amino acids |
| Dutta *et al.* (2020) | Soxhlet extraction with methanol | Leaf | Alkaloids, Steroids, Flavonoids, Tannins, Glycoside, Phenolics, Saponins |
| | | Root | Alkaloids, Steroids, Triterpenoids, Flavonoids, Tannins, Glycoside, Phenolic, Saponins |
| Gokulakrishnan *et al.* (2023) | Soxhlet extraction with ethanol | Leaf | Saponins, Alkaloids, Quinoline, Sterols, Tannins, Phenolics, Flavonoids, Glycosides |
| | | Flower | Saponins, Alkaloids, Quinoline, Sterols, Tannins, Phenolics, Flavonoids, Glycosides |
| | | Root | Saponins, Alkaloids, Quinoline, Sterols, Tannins, Phenolics, Flavonoids, Glycosides |
| | | Seed | Alkaloids, Tannins, Phenolics, Flavonoids |

## *In Silico* Molecular Docking Analysis of the Interaction of Human α-Amylase and Human α-Glucosidase with Phytochemicals of *Ruellia tuberosa* L.

Molecular docking is a prevalent computational technique employed to investigate molecular recognition, seeking to anticipate the binding configuration and strength of interaction within a complex comprising two or more molecules with established structures. This process involves positioning and evaluating ligands within the binding site of a protein, known as protein-ligand docking. The automated docking of drug-like compounds into receptors plays a crucial role in structure-based drug design, allowing for identifying molecules capable of interacting with a specific receptor to impede its activity. Such docking programs are extensively utilized to pinpoint drug-like compounds that can effectively modulate receptor function (Akshatha *et al.*, 2021). The findings from molecular docking analysis, as depicted in **Table 2**, illustrate the interaction between human α-amylase and human α-glucosidase with compounds sourced from root extracts of *Ruellia tuberosa* L.

**Table 2** Results of interaction of human α-amylase and human α-glucosidase with *Ruellia tuberosa* L. compounds by *in silico* molecular docking analysis

| | Enzyme | Extract | Compound | Energi (kJ/mol) |
|---|---|---|---|---|
| Safitri, Sari, *et al.* (2021) | α-glucosidase | - | Acarbose (as a reference) | -332.1 |
| | | Root extracts of *Ruellia tuberosa* L. | Betaine | -167.6 |
| | | | Daidzein | -249.5 |
| | | | Hispidulin | -251.2 |
| Safitri, Fatchiyah, *et al.* (2020) | α-amylase | Root extracts of *Ruellia tuberosa* L. | Betaine | -137.6 |
| | | | Daidzein | -245.8 |
| | | | Hispidulin | -236.7 |
| Safitri, Ratih, *et al.* (2020) | α-glucosidase | Root extracts of *Ruellia tuberosa* L. | Cirsimarin | -323.3 |
| | | | Cirsimaritin | -279.4 |
| | | | Sorbifolin | -256.8 |

These studies have carried out the molecular docking analysis between betaine, daidzein, hispidulin, cirsimarin, cirsimaritin, and sorbifolin to human α-glucosidase and human α-amylase protein to investigate how those ligands interact with proteins. These studies showed that these compounds exhibit the capacity to adhere to human pancreatic α-amylase and human pancreatic α-glucosidase; thus, they could serve as inhibitors. The binding energy between acarbose and human α-glucosidase, at -332.1 kJ/mol, was notably lower than other ligands, suggesting that acarbose exhibits the highest affinity for the α-glucosidase protein. The second strongest binding affinity to α-glucosidase protein was cirsimarin, with a binding energy of -323.3 kJ/mol, followed by cirsimaritin and sorbifolin, with a binding energy of -279.4 kJ/mol and -256.8 kJ/mol

respectively. Nonetheless, betaine has the weakest binding affinity both for α-glucosidase and α-amylase protein.

### *In vivo* Studies of the Antidiabetic Effects of the Extract of *Ruellia tuberosa* L. on Streptozotocin (STZ)-induced Diabetic Wistar Rats (*Rattus norvegicus*)

Chronic hyperglycemia in individuals with diabetes is believed to generate inflammation and oxidative stress, leading to an escalation in reactive oxygen species (ROS). Initiated internally, this process sets off a sequence of oxidative stress events, as reactive oxygen species (ROS) interact with polyunsaturated fatty acids (PUFAs) in cell membrane lipid bilayers, leading to lipid peroxidation. Consequently, this yields malondialdehyde (MDA) and various other detrimental aldehydes. Acting as the primary indicator of oxidative stress, MDA levels directly reflect the magnitude of damage sustained. Furthermore, oxidative stress prompts adipose tissue to secrete TNF-α, a pro-inflammatory mediator that worsens insulin resistance. Consequently, in diabetes, elevated levels of MDA and TNF-α are expected. Hence, it is anticipated that traditional medicinal plants possessing antioxidant properties can alleviate oxidative stress and reduce MDA and TNF-α levels in diabetic individuals (Armenia *et al*., 2024).

**Table 3** illustrates the outcomes of two *in vivo* experiments examining the impact of *Ruellia tuberosa* L. extracts on diabetic rats induced by streptozotocin. Streptozotocin-induced diabetic rats are frequently employed in diabetes research to mimic the disease's characteristics. In **Table 4**, Roosdiana *et al*. (2020) investigated the changes in the MDA and TNF-α levels, while in **Table 5**, Safitri, Tirto Sari, *et al*. (2021) studied its effects on the levels of blood glucose and MDA.

**Table 3** *In vivo* experimentations of *Ruellia tuberosa* L. extracts on diabetic rats induced by STZ

| | Extract | Streptozotocin induction | Group |
|---|---|---|---|
| Roosdiana *et al*. (2020) | Hydroethanolic root extracts of *Ruellia tuberosa* L. | STZ injection intraperitoneally with 20mg/kg body weight in 100mL of citrate buffer for five days consecutively | 1: Healthy rats (control) |
| | | | 2: Diabetic rats |
| | | | 3: Diabetic rats received daily doses of 250mg/kg body weight extracts |
| | | | 4: Diabetic rats received daily doses of 375mg/kg body weight extracts |
| | | | 5: Diabetic rats received daily doses of 500mg/kg body weight extracts |
| Safitri, Tirto Sari, *et al*. (2021) | Aqueous root extracts of *Ruellia tuberosa* L. | STZ injection intraperitoneally with 20mg/kg body weight for five days consecutively | 1: Healthy rats (control) |
| | | | 2: Diabetic rats |
| | | | 3: Diabetic rats received daily doses of 250mg/kg body weight extracts |
| | | | 4: Diabetic rats received daily doses of 500 mg/kg body weight extracts |
| | | | 5: Diabetic rats received daily doses of 200mg/kg metformin |

**Table 4** shows that the extract of *Ruellia tuberosa* L. reduced MDA levels and TNF-α expression in the kidneys of rats.

**Table 4** Previous research findings on the profile of the kidneys of rats

| | Group | MDA levels on the rats' kidney (µg/mL)∗ | Changes (%) | TNF-α expression on kidney (µg/dL)∗ | Changes (%) |
|---|---|---|---|---|---|
| Roosdiana *et al*. (2020) | 1 | $1.07\pm0.21^{a}$ | | $18.87\pm4.85^{a}$ | |
| | 2 | $4.08\pm0.10^{e}$ | ↑281.31 | $53.65\pm14.12^{e}$ | ↑185.23 |
| | 3 | $1.93\pm0.18^{b}$ | ↓52.70 | $31.47\pm4.90^{b}$ | ↓42.24 |
| | 4 | $2.41\pm0.11^{c}$ | ↓40.93 | $34.70\pm3.20^{c}$ | ↓35.51 |
| | 5 | $2.85\pm0.14^{d}$ | ↓30.15 | $42.92\pm10.53^{d}$ | ↓20.12 |

Note: Different notations point to significant contrasts between treatments ($p<0.05$)

**Table 4** illustrates that within the diabetic group (group 2), there was a notable surge in MDA levels, escalating by up to 281%. Following the administration of *Ruellia tuberosa* L. extracts, a significant decrease in MDA

levels was observed in the treated groups (groups 3, 4, and 5) at a significance level of $p<0.05$. The administration of the lowest dose at 250 mg/kg body weight resulted in the highest decrease, amounting to 52.70%. In contrast, the highest dosage of 500 mg/kg body weight resulted in a comparatively modest decline of 30.15% in MDA levels, marking the least reduction among the treatments.

Apart from that, there was a significant rise (185%) in TNF-α expression within the diabetic cohort (group 2) subsequent to streptozotocin induction. This elevation in TNF-α expression is a reaction to the heightened tissue inflammation characteristic of diabetic conditions. Post-treatment interventions led to a notable reduction in TNF-α expression. Administration of a dosage of 250 mg/kg body weight produced the most substantial decrease (42.24%) in TNF-α expression. Following this, 375 mg/kg and 500 mg/kg body weight doses decreased by 35.51% and 20.12% in TNF-α expression, respectively.

The TNF-α expression declined across all three treatment groups due to administering therapy with *Ruellia tuberosa* L. root extract, which decreased ROS activity. The extracts could potentially mitigate kidney inflammation through direct or indirect mechanisms, such as lowering hyperglycemia and oxidative stress levels. Flavonoid compounds extracted from *Ruellia tuberosa* L. roots demonstrated anti-inflammatory effects by suppressing the expression of proinflammatory cytokines or by reducing ROS production (Roosdiana *et al.*, 2020).

In **Table 5**, this study found that the extract of *Ruellia tuberosa* L. lowered the blood glucose levels, the level of MDA serum, and the MDA level in the rats' pancreas.

**Table 5** The ability of *Ruellia tuberosa* L. extracts in lowering blood glucose and MDA levels

| | Group | Blood glucose level (mg/dL)∗ | Changes (%) | Serum MDA level (µg/dL)∗ | Changes (%) | MDA level on pancreas (µg/dL)∗ | Changes (%) |
|---|---|---|---|---|---|---|---|
| Safitri, Tirto Sari, *et al.* (2021) | 1 | $131.2\pm18.12^{a}$ | | $1.27\pm0.18^{a}$ | | $0.237\pm0.03^{a}$ | |
| | 2 | $523.8\pm17.99^{e}$ | ↑299.24 | $6.96\pm0.41^{e}$ | ↑448.03 | $0.75\pm0.12^{d}$ | ↑216.45 |
| | 3 | $454.6\pm12.52^{d}$ | ↓13.21 | $6.04\pm0.15^{d}$ | ↓13.22 | $0.69\pm0.09^{d}$ | ↓8.0 |
| | 4 | $391.2\pm17.44^{c}$ | ↓25.35 | $4.55\pm0.33^{c}$ | ↓34.63 | $0.66\pm0.07^{c}$ | ↓12.0 |
| | 5 | $165.4\pm13.55^{ab}$ | ↓68.42 | $2.35\pm0.45^{b}$ | ↓66.24 | $0.367\pm0.03^{b}$ | ↓51.07 |

Note: Different notations point to significant contrasts between treatments ($p<0.05$)

**Table 5** presents the impact of *Ruellia tuberosa* L.'s aqueous root extracts on rat blood glucose levels. The diabetic rats have significantly elevated glucose levels, amounting to 299.24% compared to the normal group. The oral administration of either the extracts (at doses of 250 and 500 mg/kg) or metformin (200 mg/kg) decreased blood glucose levels in the rats. However, administering the maximum dose of *Ruellia tuberosa* L. root extracts led to a 25.35% decrease in diabetes, whereas the metformin-treated group experienced a significant 68.42% reduction in blood glucose levels.

The extracts of *Ruellia tuberosa* L. exhibit further hypoglycemic effects, as evidenced by reductions in MDA levels. **Table 5** displays the measured MDA concentrations. In the diabetic group without treatment, MDA concentrations surged to 448% in serum and 216.5% in the pancreas. Following treatment, there was a notable decrease in MDA levels among the treated groups (groups 3, 4, and 5) with statistical significance ($p<0.05$). The highest administered dose (500 mg/kg body weight) led to substantial reductions in MDA levels, with decreases of 12% in the pancreas and 34.6% in serum.

## CONCLUSION

In conclusion, this literature review showed that different parts of *Ruellia tuberosa* L. extracts, including root, leaf, flower, seed, and tuber, contain secondary metabolite compounds such as alkaloids, amino acids, ascorbic acids, carbohydrates, flavonoids, glycosides, phenolics, quinoline, saponins, steroids, sterols, tannins, and terpenoids. The molecular docking analysis of cirsimarin to human α-glucosidase and human α-amylase protein showed the second strongest binding affinity after acarbose. Lastly, the root extracts of *Ruellia tuberosa* L. lowered the blood glucose level, MDA level, and TNF-α expression. Thus, evidence from these studies suggests that *Ruellia tuberosa* L. extracts could be explored as antidiabetic medications due to their advantageous outcomes for diabetes and its associated complications. Nonetheless, additional molecular and cellular investigations are necessary to explore the underlying mechanisms behind these favorable effects.

## CONFLICT OF INTEREST

The authors declare no conflict of interest.

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