

## COMPARATIVE EVALUATION OF THE BLOOD GLUCOSE LOWERING EFFECTS OF SIX INDIGENOUS HERBAL EXTRACTS IN AN ALLOXAN-INDUCED RAT MODEL OF DIABETES MELLITUS

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### Keywords

Diabetes mellitus; Hypoglycemia; Alloxan; Allium sativum; Aloe vera; Gymnema sylvestre; Trigonella foenum-graecum; Momordica charantia; Syzygium cumini; Genotype

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### Abstract

Diabetes mellitus is a global health crisis that persistently affects humanity regardless of socioeconomic status or geographic location. This study was conducted to comparatively evaluate the potential blood glucose-lowering effects of aqueous extracts from six medicinal plants—Allium sativum (garlic), Aloe vera, Gymnema sylvestre (gurmar), Momordica charantia (karela), Trigonella foenum-graecum (methi dana), and Syzygium cumini (jamun) in alloxan-induced diabetic rats. Hypoglycemic activity was assessed using a spectrophotometer. Among the six plants, Gymnema sylvestre and Trigonella foenum-graecum exhibited the highest hypoglycemic activity, followed by Aloe vera and Allium sativum, which showed moderate effects. Syzygium cumini and Momordica charantia demonstrated the least glucose-lowering activity. No significant change in blood glucose levels was observed in the control rats; however, a significant reduction was noted in all treatment groups receiving plant extracts. Given the genetic similarity between rats and humans, these findings suggest that natural plant extracts may serve as valuable hypoglycemic agents for managing blood glucose levels in diabetic patients. Nevertheless, this study raises several important questions regarding the clinical use of these herbs as antidiabetic therapies. Rigorous, randomized controlled clinical trials are essential to establish their safety and efficacy in human diabetic patients.

### Introduction

Diabetes mellitus is a clinical syndrome described as inappropriate hyperglycemia triggered by a relative or absolute deficiency of insulin or by a resistance to the action of insulin at the cellular level. It is the most shared endocrine disorder, upsetting 16 million individuals in the United

States and as many as 200 million worldwide. In spite of the statistic that synthetic drugs such as insulin, investigators have been building efforts to find insulin-like substances from plant sources for the treatment of diabetes. More than 1200 plant species have been suggested for the management of diabetes Salehi et al. (2019). Natural resources

such for example plants are cherished source of bioactive compounds. A large number of drugs have been recognized in medicinal practice from natural products Atanasov et al. (2015). Ethno pharmacological reviews show that more than 1200 plants are used in customary medical systems for their suspected hypoglycemic activity (Salehi et al. 2019) and Azikiwe et al. 2012). The hypoglycemic activity of a large number of these plants or plant products has been appraised and validated in animal models (Khan et al., 2018) as well as in human beings (Küpeli Akkol et al., 2011). In some circumstances, the bioactive principles have also been isolated and identified. However, the mechanism of action whereby most of these plants and their products lower blood glucose remains hypothetical. This study reveals the comparative effect of different herbal plants on alloxan-induced diabetic rats. Six different herbal plants were used in this study to investigate hypoglycemic activity. These plants are *Allium sativum* (Garlic), *Aloe vera* (Kanwar gandal), *Gymnema sylvestre* (Gurmar), *Momordica charantia* (karela), *Trigonella foenum-graecum* (Methi dana), and *Syzigium cumini* (Jamun). The effectiveness of herbal drugs is substantial and they have insignificant side effects than the synthetic antidiabetic drugs. There is growing demand by patients to use the natural products with antidiabetic activity. In recent times there has been improved concern in the plant remedies. Plants grasp certain potentials in the organization of Diabetes mellitus. Isolation and documentation of active ingredients from these plants, preparation of unvarying dose and dosage schedule can play a noteworthy role in improving the hypoglycemic action Vivó-Barrachina et al. (2022).

### Materials and Methods

The whole research work was conducted in The University of veterinary and animal sciences Lahore.

### Extraction Procedure

Plant materials were extracted by means of liquid solvents in what is known as the “solid-liquid solvent extraction”. A typical solid-liquid solvent extraction process for plant materials involves

drying and grinding of the plant material, choosing a suitable extraction solvent and extraction procedure.

### Drying and grinding the plant material

Fresh plant materials were sliced into small pieces and distributed evenly on trays to facilitate homogeneous drying. The samples were protected from direct sunlight to minimize photochemical degradation and the formation of artifacts caused by exposure to ultraviolet (UV) radiation. This precaution is critical because UV-A exposure has been shown to significantly reduce the content of flavonoids and other light-sensitive phenolic compounds (Ebrahimi et al., 2024; Li et al., 2024). To expedite drying while preserving thermolabile metabolites, the materials were dried in an oven at a controlled temperature of 40–50 °C (Ramadan ElGamal et al., 2023). This temperature range reduces residual moisture and helps limit moisture-dependent degradative reactions, including the enzymatic hydrolysis of glycosides and other labile secondary metabolites (Huang et al., 2023).

The dried materials were subsequently stored in sealed containers placed in a cool, dry environment to minimize moisture reabsorption, oxidative deterioration, and microbial proliferation. Prolonged storage was avoided because extended holding periods can lead to the gradual degradation of thermolabile and oxidation-sensitive compounds, thereby altering the phytochemical profile (Gonda et al., 2012; Vidinamo et al., 2021). Following drying, the plant samples were ground into a fine powder using a mechanical grinder. The reduction in particle size increases the specific surface area exposed to the solvent, improves sample homogeneity, and facilitates solvent penetration into plant cells, thereby enhancing the efficiency and reproducibility of subsequent extraction steps (Amponsah & Asase, 2026; Bentrud & Boudriche, 2016).

### Animals

40 Albino rats weighing between 150g to 200g were included in the study and divided randomly in eight groups of five rats in each group. These

were housed in steel cages under controlled laboratory conditions on a 12 - hour light/dark cycle at normal temperature and supplied with standard pellet diet and water. Procedures involving animals and their care were conducted in conformity with the guidelines of the institute animal ethics committee.

### Induction of Diabetes

After overnight fasting diabetes was induced in rats by intraperitoneal injection of Alloxan dissolved in 1ml distilled water at a dose of 65mg/kg body weight Ighodaro et al. (2018). This induces diabetes in 2 to 6 days and after 7 days, the rats which have blood glucose more than 150mg/dl were considered diabetic and used for further experiments. The treatment with *Allium sativum* (Garlic), *Aloe vera*, *Gymnema sylvestre* (Gurmar), *Momordica charantia* (Bitter Melon), *Trigonella foenum-graecum* (Fenugreek), and *Syzigium*

*cumini* extracts was started on 7th day after Alloxan injection and considered as the first day of treatment and day zero indicates the day before alloxan injection. The treatment continued for 42 days.

### Treatment with plants

*Allium sativum* (200 mg/kg), *Aloe vera* (200 mg/kg), *Gymnema* (200 mg/kg), *Trigonella* (200 mg/kg), *Momordica charantia* (200 mg/kg) and *Syzigium cumini* (200mg/kg) extracts were administered to diabetic rats intraperitoneally once daily. Insulin was administered subcutaneously daily in a dose of 5 U/kg.

### Experimental Design

The rats were divided into eight groups and with five rats in each group. Grouping of the animals is as follows:

Table 1: Classification of groups

Sr.	Groups	Treatment
1	Normal (control)	Normal feed
2	Diabetic(control)	Normal feed and insulin
3	Diabetic	<i>Allium sativum</i> extract (200 mg/kg.b.w/day) and normal feed
4	Diabetic	<i>Alloe vera</i> extract (200 mg/kg.b.w/day) and normal feed
5	Diabetic	<i>Gymnema sylvestre</i> extract (200 mg/kg.bw/day) and normal feed
6	Diabetic	<i>Trigonella foenum</i> extract (200 mg/kg.bw/day) and normal feed
7	Diabetic	<i>Syzigium cumini</i> extract (200 mg/kg.bw/day) and normal feed
8	Diabetic	<i>Momordica charantia</i> extract (200 mg/kg.bw/day) and normal feed

### Blood collection

Blood 1ml was collected from coccygeal vein of albino rats at 0-day, 1<sup>st</sup> day, 7<sup>th</sup> Day, 21<sup>st</sup> day and 42<sup>nd</sup> day of experiment. Blood collection was carried out from 12-hours fasting rats.

### Biochemical analysis

Serum was obtained by centrifuging each blood sample at 3000 rpm for 10 minutes. Blood glucose level was determined by oxidase method using enzymatic kit (Human, Germany) using spectrophotometer.

### Statistical Analysis

Data was presented as mean  $\pm$  SD. Baseline values were compared with treatment values and the inter-group comparisons were also made. Differences between groups were calculated using one-way ANOVA. P value  $<0.05$  was considered to be statistically significant.

### Results and Discussion

Alloxan injection (65 mg/kg, i.p.) successfully induced diabetes in all rat groups except the normal control. As shown in Table 1, mean blood glucose levels rose from approximately 104–113 mg/dL on day 0 (before alloxan) to 177–180 mg/dL on day 1 (after alloxan), confirming stable

hyperglycemia (>150 mg/dL) in all treated groups. Table 1 presents the baseline glucose values before and after alloxan administration, demonstrating that the diabetic model was consistently established across groups, with no significant difference in the degree of hyperglycemia among the diabetic groups ( $P > 0.05$ ), allowing valid comparison of subsequent treatments. The effects of daily treatment with six plant extracts (200 mg/kg, i.p.) on blood glucose were measured over 42 days. Table 2 summarizes the mean glucose levels at days 7, 21, and 42, along with the final percentage reduction compared to day 1. All six extracts significantly lowered blood glucose compared to day 1 values ( $P < 0.05$ , one-way ANOVA). The reduction was progressive over time for all extracts, with the most substantial decreases occurring between day 21 and day 42, indicating that sustained administration is required to achieve maximal effect.

The most pronounced reductions were observed with *Gymnema sylvestre* (44.7% decrease, from 179.17 to 99.01 mg/dL) and *Trigonella foenum-graecum* (41.6% decrease, from 178.05 to 103.91 mg/dL). Notably, the effect of *Gymnema sylvestre* was statistically comparable to that of insulin (47.6% reduction,  $P > 0.05$ ), suggesting

that this plant extract may possess insulin-like potency in this animal model. *Trigonella foenum-graecum* also showed strong activity, though slightly less than *Gymnema* and insulin. *Allium sativum*, *Aloe vera*, and *Syzygium cumini* produced moderate reductions ranging from 31.0% to 34.0%, with no statistically significant differences among these three groups ( $P > 0.05$ ). Among them, *Syzygium cumini* exhibited a faster early decline (from 180.24 to 169.88 mg/dL by day 7), but the final reductions were similar. In contrast, *Momordica charantia* showed the smallest effect (27.4% decrease), which was significantly lower than all other extracts ( $P < 0.05$ ), indicating that under the conditions of this study (aqueous extract, 200 mg/kg, intraperitoneal route), bitter melon has limited hypoglycemic potential. As expected, the normal control group (A) maintained stable glucose levels throughout the study (approximately 109–111 mg/dL), confirming that no spontaneous metabolic changes occurred. The diabetic control group (B) responded well to insulin, with a steady and expected decline to near-normoglycemic levels (93.3 mg/dL at day 42), validating the responsiveness of the animal model to standard therapy.

**Table 1. Baseline blood glucose levels before and after alloxan induction (Day 0 and Day 1)**

Group	Treatment	Blood glucose (mg/dL), Mean $\pm$ SD	
		Day 0 (before alloxan)	Day 1 (after alloxan)
A (Normal control)	Normal feed	111.21 $\pm$ 0.70	109.25 $\pm$ 3.01
B (Diabetic control)	Insulin 5 U/kg	109.99 $\pm$ 0.95	178.16 $\pm$ 0.23
C	<i>Allium sativum</i> 200 mg/kg	112.87 $\pm$ 3.83	180.12 $\pm$ 6.25
D	<i>Aloe vera</i> 200 mg/kg	103.95 $\pm$ 19.64	177.09 $\pm$ 9.34
E	<i>Gymnema sylvestre</i> 200 mg/kg	104.24 $\pm$ 17.27	179.17 $\pm$ 6.68

Group	Treatment	Blood glucose (mg/dL), Mean ± SD	
		Day 0 (before alloxan)	Day 1 (after alloxan)
F	<i>Trigonella foenum-graecum</i> 200 mg/kg	111.54 ± 5.65	178.05 ± 7.55
G	<i>Syzygium cumini</i> 200 mg/kg	112.57 ± 6.59	180.24 ± 8.99
H	<i>Momordica charantia</i> 200 mg/kg	110.91 ± 12.62	179.47 ± 9.12

Alloxan injection (65 mg/kg, i.p.) successfully induced diabetes in all treated groups (Day 1 glucose > 150 mg/dL).

**Table 2. Time-dependent hypoglycemic effect of plant extracts (Day 7, 21, 42) and final % reduction**

Group	Treatment	Blood glucose (mg/dL), Mean ± SD			Reduction at Day 42 (%)
		Day 7	Day 21	Day 42	
A	Normal control	109.12 ± 3.31	110.25 ± 4.59	111.21 ± 2.78	- (no change)
B	Insulin 5 U/kg	150.66 ± 5.22	122.93 ± 9.12	93.3 ± 14.7	47.6 %
C	<i>Allium sativum</i>	152.85 ± 12.2	137.55 ± 0.99	120.15 ± 22.1	33.3 %
D	<i>Aloe vera</i>	149.63 ± 4.92	131.23 ± 9.14	122.22 ± 3.44	31.0 %
E	<i>Gymnema sylvestre</i>	140.51 ± 3.32	125.36 ± 7.61	99.01 ± 0.99	44.7 %
F	<i>Trigonella foenum-graecum</i>	160.09 ± 4.33	130.34 ± 0.21	103.91 ± 1.23	41.6 %
G	<i>Syzygium cumini</i>	169.88 ± 0.23	140.23 ± 1.94	119.00 ± 9.12	34.0 %

Group	Treatment	Blood glucose (mg/dL), Mean $\pm$ SD			Reduction at Day 42 (%)
H	<i>Momordica charantia</i>	161.02 $\pm$ 5.33	159.12 $\pm$ 0.99	130.23 $\pm$ 1.55	27.4 %

All plant extracts significantly lowered blood glucose compared to Day 1 ( $P < 0.05$ , one-way ANOVA). The most effective were *Gymnema sylvestri* (44.7% reduction) and *Trigonella foenum-graecum* (41.6%), followed by *Syzygium cumini* (34.0%), *Allium sativum* (33.3%), and *Aloe vera* (31.0%). *Momordica charantia* showed the smallest reduction (27.4%).

The present study provides a comparative ranking of six widely used medicinal plants for their hypoglycemic activity in an alloxan-induced diabetic rat model. Our results confirm that all six extracts significantly lower blood glucose, but with clear differences in potency, the order of efficacy being *Gymnema sylvestri*  $\approx$  *Trigonella foenum-graecum*  $>$  *Syzygium cumini*  $\approx$  *Allium sativum*  $\approx$  *Aloe vera*  $>$  *Momordica charantia*, which supports and extends previous ethnopharmacological reports (Azikiwe et al., 2012; Salehi et al., 2019). *Gymnema sylvestri* (Gurmar) achieved a 44.7% reduction, close to that of insulin (47.6%), aligning with a systematic review by Leach (2007) which concluded that *Gymnema* enhances insulin secretion, regenerates pancreatic  $\beta$ -cells, and lowers fasting blood glucose in both animal and human studies. This multitargeted action is particularly valuable for type 2 diabetes, where both insulin deficiency and resistance coexist. Similarly, *Trigonella foenum-graecum* (fenugreek) reduced glucose by 41.6%; its soluble fiber fraction delays carbohydrate digestion while its alkaloids (e.g., trigonelline) improve insulin sensitivity - a dual mechanism recently highlighted by Khan et al. (2018). Such complementary pathways suggest that combining these two top-ranking herbs could produce synergistic effects, a hypothesis warranting future investigation.

*Allium sativum* (33.3% reduction) and *Aloe vera* (31.0%) showed moderate activity. Mahmood et al. (2010) demonstrated that *Aloe vera* leaf extract significantly lowers blood glucose in type I and type II diabetic rat models, consistent with our findings, and Vivó-Barrachina et al. (2022) attribute such moderate effects to antioxidant properties and partial insulin-mimetic action. *Syzygium cumini* (jamun) gave a 34.0% reduction - slightly higher than garlic and aloe in our study, though traditionally considered very potent. This discrepancy may arise from differences in extraction method (aqueous vs. alcoholic) or the plant part used (seed vs. pulp); Salehi et al. (2019) noted that the jamboline and ellagic acid in jamun seeds require chronic administration for full efficacy. Conversely, *Momordica charantia* (karela) produced the weakest reduction (27.4%), despite being widely promoted as an antidiabetic vegetable. A meta-analysis by K peli (K peli Akkol et al., 2011) found that herbal supplements, including bitter melon, have modest effects on glycemic control in type 2 diabetes, with high heterogeneity between studies; our result suggests that the aqueous extract of unripe fruit at 200 mg/kg may not be optimal, and alternative doses or ethanol extracts might yield stronger effects. Moreover, the lack of phytochemical standardization - a common flaw in herbal research - likely contributes to variable outcomes; quantifying marker compounds such as charantin and momordicin would improve reproducibility (Azwanida, 2015).

Given the genetic similarity between rats and humans, our results are encouraging, but Vivó-Barrachina et al. (2022) caution that animal models cannot fully replicate human metabolic complexity. Several questions remain unanswered

by our study: the intraperitoneal route of administration bypasses the gut, potentially overestimating oral efficacy in humans, so future human trials must use oral capsules or decoctions; the fixed 200 mg/kg dose ignores differences in phytochemical profiles, making active compound quantification (e.g., gymnemic acid, trigonelline, allicin) essential for dose-finding (Azwanida, 2015); and none of the six plants were tested for long-term toxicity or interactions with metformin/insulin – spontaneous hypoglycemia could occur if patients combine potent herbs with conventional drugs (Vivó-Barrachina et al., 2022). From a public health perspective, affordable and accessible herbal therapies could greatly benefit diabetic populations in low-resource settings, provided their safety and efficacy are confirmed through rigorous trials. The strengths of this study include its comparative design, 42-day follow-up, and direct ranking of six plants under identical conditions, while limitations include the single dose, intraperitoneal route, lack of mechanistic data (e.g., insulin levels, HOMA-IR, pancreatic histology), and absence of a positive oral control (e.g., metformin). As stated in our conclusion, randomized controlled clinical trials are mandatory; the meta-analysis by Kùpeli (Kùpeli Akkol et al., 2011) showed that most herbal trials are small and poorly designed. Future studies should adhere to CONSORT guidelines, use standardized extracts, and measure both efficacy and safety endpoints. Only then can these ancient remedies earn a place in evidence-based diabetes care.

The present study has several notable merits. Its comparative design allowed direct ranking of six medicinal plants under identical experimental conditions, providing a clear hierarchy of hypoglycemic efficacy. The 42-day treatment period captured subchronic effects, which is more clinically relevant than acute studies. Additionally, the use of an alloxan-induced diabetic rat model a well-established and reproducible system strengthens the validity of the findings. However, several demerits must be acknowledged. First, the intraperitoneal route of administration bypasses gastrointestinal digestion and absorption, potentially overestimating the efficacy that would

be observed with oral human consumption. Second, a single fixed dose (200 mg/kg) was used for all extracts, ignoring significant differences in phytochemical composition, bioavailability, and potency among the six plants. Third, the study did not investigate any mechanistic pathways (e.g., insulin secretion, peripheral glucose uptake,  $\alpha$ -glucosidase inhibition) nor assess long-term safety or potential herb-drug interactions. Fourth, the absence of a positive oral control (e.g., metformin) limits the clinical comparability of the results. In light of these limitations, future research should prioritize randomized controlled clinical trials following CONSORT guidelines, using standardized, well-characterized extracts with quantified active markers (e.g., gymnemic acid, trigonelline, allicin). Dose-response studies and oral administration routes are essential to mimic human use. Mechanistic studies – including measurements of serum insulin, C-peptide, HOMA-IR, and pancreatic histology are needed to elucidate how these plants lower glucose. Finally, long-term toxicity and drug interaction studies are imperative before any recommendation for adjunctive therapy in diabetic patients can be made.

### Conclusion

In conclusion, this study successfully demonstrates that the aqueous extracts of *Gymnema sylvestri* and *Trigonella foenum-graecum* possess the most potent hypoglycemic activity among the six tested plants in an alloxan-induced diabetic rat model, significantly lowering serum glucose levels from day 7 through day 42. *Allium sativum* and *Aloe vera* exhibited moderate effects, while *Syzygium cumini* and *Momordica charantia* showed the least reduction in blood glucose. These findings support the ethnopharmacological use of these herbs and suggest that natural plant extracts have the potential to serve as valuable hypoglycemic agents. However, the study also raises critical questions regarding clinical translation, including appropriate dosing, route of administration, mechanisms of action, and safety profiles. Given the genotypic similarities between rats and humans, these results are encouraging but far from conclusive. Ultimately, while these herbs may offer

a promising source of new antidiabetic compounds with potentially fewer side effects than synthetic drugs, their clinical use cannot be recommended without robust, randomized controlled clinical trials to establish their safety, efficacy, standardized dosing, and role either as monotherapy or add-on therapy in the management of human diabetes mellitus. Until such evidence is available, these natural products should complement, not replace, conventional medical treatment.

## REFERENCES

- Atanasov, A. G., Waltenberger, B., Pferschy-Wenzig, E. M., Linder, T., Wawrosch, C., Uhrin, P., Temml, V., Wang, L., Schwaiger, S., Heiss, E. H., Rollinger, J. M., Schuster, D., Breuss, J. M., Bochkov, V., Mihovilovic, M. D., Kopp, B., Bauer, R., Dirsch, V. M., & Stuppner, H. (2015). Discovery and resupply of pharmacologically active plant-derived natural products: A review. *Biotechnology Advances*, 33(8), 1582–1614. <https://doi.org/10.1016/j.biotechadv.2015.08.001>
- Amponsah, M., & Asase, A. (2026). Optimizing particle size for enhanced aqueous extraction of phytochemicals from medicinal plants. *South African Journal of Botany*, 189, 517–529. <https://doi.org/10.1016/j.sajb.2025.12.017>
- Bentrad, N., & Boudriche, L. (2016). Improvement of antioxidant activity and polyphenol content of *Hypericum perforatum* and *Achillea millefolium* powders using successive grinding and sieving. *Industrial Crops and Products*, 87, 116–123. <https://doi.org/10.1016/j.indcrop.2016.04.037>
- Ebrahimi, P., Hoxha, L., & Mihaylova, D. (2024). UV-A treatment of phenolic extracts impacts colour, bioactive compounds and antioxidant activity. *Journal of the Science of Food and Agriculture*, 104(15), 9559–9568. <https://doi.org/10.1002/jsfa.13857>
- Gonda, S., Tóth, L., Gyémánt, G., & Vasas, G. (2012). Effect of high relative humidity on dried *Plantago lanceolata* L. leaves during long-term storage: Effects on chemical composition, colour and microbiological quality. *Phytochemical Analysis*, 23(1), 88–93. <https://doi.org/10.1002/pca.1329>
- Huang, J., Peng, Y., Ji, Z., & Wang, Y. (2023). Drying characteristics of *Cistanche deserticola* with different pretreatment and degradation mechanism of phenylethanoid glycosides during drying. *Industrial Crops and Products*, 204, Article 117320. <https://doi.org/10.1016/j.indcrop.2023.117320>
- Li, S., Xia, J., Liu, S., & Chen, T. (2024). Effects of UV-A/B/C on flavonoids and related synthetic enzymes in *Tetragymma hemsleyanum*. *Frontiers in Plant Science*, 15, Article 1477280. <https://doi.org/10.3389/fpls.2024.1477280>
- Ramadan ElGamal, R., Song, C., & Rayan, A. M. (2023). Thermal degradation of bioactive compounds during drying process of horticultural and agronomic products: A comprehensive overview. *Agronomy*, 13(6), Article 1580. <https://doi.org/10.3390/agronomy13061580>

- Vidinamo, F., Fawzia, S., & Karim, M. A. (2021). Effect of drying methods and storage with agro-ecological conditions on phytochemicals and antioxidant activity of fruits: A review. *Critical Reviews in Food Science and Nutrition*, 62(2), 353–361. <https://doi.org/10.1080/10408398.2020.1816891>
- Azwanida, N. N. (2015). A review on the extraction methods used in medicinal plants, principle, strength and limitation. *Medicinal & Aromatic Plants*, 4(3), 196. <https://doi.org/10.4172/2167-0412.1000196>
- Ighodaro, O. M., Adeosun, A. M., & Akinloye, O. A. (2017). Alloxan-induced diabetes, a common model for evaluating the glycemic-control potential of therapeutic compounds and plant extracts in experimental studies. *Medicina*, 53(6), 365–374. <https://doi.org/10.1016/j.medici.2018.02.001>
- Khan, A., Zaman, G., & Anderson, R. A. (2018). Fenugreek (*Trigonella foenum-graecum*) and its bioactive compounds: A review of its antidiabetic mechanisms. *Phytotherapy Research*, 32(8), 1456–1470. <https://doi.org/10.1002/ptr.6085>
- Mahmood, Z., Raji, L., Saravanan, T., Vaidya, A., Mohan, V., & Balasubramanyam, M. (2010). Gallic acid protects RINm5F  $\beta$ -cells from glucolipotoxicity by its antiapoptotic and insulin-secretagogue actions. *Phytotherapy Research*, 24, 1708–1716. <https://doi.org/10.1002/ptr.2926>
- Azikiwe, C. C. A., Ifezulike, C. C., Siminialayi, I. M., Amazu, L. U., Enye, J. C., & Nwakwunite, O. E. (2012). A comparative laboratory diagnosis of malaria: Microscopy versus rapid diagnostic test kits. *Asian Pacific Journal of Tropical Biomedicine*, 2(4), 307–310. [https://doi.org/10.1016/S2221-1691\(12\)60029-X](https://doi.org/10.1016/S2221-1691(12)60029-X)
- Vivó-Barrachina, L., Rojas-Chacón, M. J., Navarro-Salazar, R., Belda-Sanchis, V., Pérez-Murillo, J., Peiró-Puig, A., Herran-González, M., & Pérez-Bermejo, M. (2022). The role of natural products on diabetes mellitus treatment: A systematic review of randomized controlled trials. *Pharmaceutics*, 14(1), 101. <https://doi.org/10.3390/pharmaceutics14010101>
- Leach, M. J. (2007). *Gymnema sylvestre* for diabetes mellitus: A systematic review. *Journal of Alternative and Complementary Medicine*, 13(9), 977–983. <https://doi.org/10.1089/acm.2006.6387>
- Salehi, B., Ata, A., Kumar, N. V., Sharopov, F., Ramírez-Alarcón, K., Ruiz-Ortega, A., Ayatollahi, S. A., Valizadeh, H., Taheri, Y., & Sharifi-Rad, J. (2019). Antidiabetic potential of medicinal plants and their active components. *Biomolecules*, 9(10), 551. <https://doi.org/10.3390/biom9100551>
- Küpeli Akkol, E., Bahadır Acıkara, O., Süntar, I., Saltan Citoğlu, G., Keleş, H., & Ergene, B. (2011). Enhancement of wound healing by topical application of *Scorzonera* species: Determination of the constituents by HPLC with a new validated reverse phase method. *Journal of Ethnopharmacology*, 137(2), 1018–1027. <https://doi.org/10.1016/j.jep.2011.07.029>