

Synergistic Effects of Co Administration of Aqueous Ginger Extract and Glibenclamide on Glycaemic Status and Antioxidant Defence in Alloxan Induced Diabetic Wistar Rats

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Abstract

Diabetes mellitus is linked with persistent hyperglycaemia, oxidative stress and tissue damage, especially in the pancreas, liver and kidney. This study examined the possible synergistic effects of aqueous ginger extract and glibenclamide on fasting blood sugar and antioxidant status in alloxan induced diabetic Wistar rats. Thirty five rats were used. Diabetes was induced with alloxan, and rats with fasting blood sugar above 7.0 mmol/L were selected for treatment. The animals were divided into five groups: normal control, diabetic untreated, ginger treated, ginger + glibenclamide treated and glibenclamide treated. Treatment lasted for 28 days. Fasting blood sugar was measured on days 0, 14 and 28, while the pancreas, liver and kidneys were analyzed for reduced glutathione, glutathione S transferase, superoxide dismutase and lipid peroxidation.

The diabetic untreated group showed increased fasting blood sugar, reduced antioxidant defence and elevated lipid peroxidation. Ginger and glibenclamide improved glycaemic control and antioxidant markers when administered separately. However, the combined treatment produced the strongest effect, reducing fasting blood sugar from 7.36 ± 0.9 mmol/L to 2.3 ± 0.9 mmol/L by day 28 and improving antioxidant enzyme activities in the pancreas, liver and kidney. The findings suggest that ginger may enhance the antidiabetic and antioxidant effects of glibenclamide, although the very low glucose level indicates possible hypoglycaemic risk.

Keywords: Alloxan, diabetes mellitus, ginger, glibenclamide, oxidative stress, lipid peroxidation, Wistar rats

Introduction

Diabetes mellitus is a chronic metabolic disorder characterized by persistent elevation of blood glucose due to impaired insulin secretion, impaired insulin action, or both (Jadon *et al.*, 2024). Chronic hyperglycaemia is not only a marker of poor glucose regulation but also a major driver of oxidative stress, inflammation, and tissue damage (González *et al.*, 2023). Oxidative stress contributes to diabetic complications by impairing pancreatic beta cell function, disrupting antioxidant defence systems, and damaging cellular lipids, proteins, and nucleic acids. Recent reviews continue to identify oxidative stress as a central mechanism in the development and progression of diabetes and its complications (Dinić *et al.*, 2022).

Alloxan is widely used to induce experimental diabetes in rodents because of its selective toxic effect on pancreatic beta cells. Its diabetic action is strongly linked with reactive oxygen species generation and pancreatic beta cell damage, making it useful for studying hyperglycaemia, oxidative stress, and potential antidiabetic interventions (Longkumer *et al.*, 2021). In diabetic experimental models, the resulting imbalance between free radical production and endogenous

antioxidant defence can be assessed through markers such as reduced glutathione, glutathione S transferase, superoxide dismutase, and lipid peroxidation (Engwa *et al.*, 2022).

Glibenclamide is a sulfonylurea antidiabetic drug that lowers blood glucose mainly by stimulating insulin release from pancreatic beta cells. This mechanism depends on the functional capacity of surviving beta cells, which makes it relevant in experimental diabetes models where partial beta cell damage may still permit drug response. Sulfonylureas stimulate insulin secretion by acting on pancreatic beta cell potassium channels, leading to membrane depolarization and insulin release (Tomlinson *et al.*, 2022).

Ginger, scientifically known as *Zingiber officinale*, is a medicinal plant with reported antioxidant, anti-inflammatory, and glucose lowering properties. Its bioactive constituents, including 6-shogaol, gingerols and other related phenolic compounds, have been associated with improved antioxidant enzyme activity and modulation of glucose metabolism (Ayustaningwarno *et al.*, 2024). Clinical and experimental studies have reported that ginger may reduce fasting blood glucose and improve antioxidant status, making it a useful candidate for combination studies in diabetes research (Rostamkhani *et al.*, 2023).

The combined use of plant derived antioxidants with conventional antidiabetic drugs is of scientific interest because such combinations may produce complementary or synergistic effects (Ebadi, 2025). Ginger may support antioxidant defence and reduce oxidative injury, while glibenclamide directly promotes insulin secretion. A previous study comparing ginger and glibenclamide on oxidative stress markers also supports the relevance of examining both agents in diabetic models (Siregaret *et al.*, 2022). Therefore, this study investigated the synergistic effects of co administration of aqueous ginger extract and glibenclamide on fasting blood sugar and selected antioxidant and peroxidative markers in the pancreas, liver, and kidney of alloxan induced diabetic Wistar rats.

Materials and Methods

Study animals

Thirty five healthy wistar rats were used for the study. The animals were kept in clean laboratory cages under standard environmental conditions, with access to feed and water. They were allowed to acclimatize before the commencement of the experiment. Rats were maintained in accordance with the Animal Ethics Committee's guide for the care and use of animals in research and education and the National Institutes of Health's guide for the care and use of laboratory animals (NIH Publications No. 8023, revised 1978). The experimental protocol was approved in accordance with ethical standards

Identification and Preparation of aqueous ginger extract

Fresh leaf of ginger was collected and identified in the herbarium and a voucher number was assigned. Fresh ginger rhizomes were obtained, washed thoroughly with clean water to remove soil and debris, and the back peeled off. The cleaned rhizomes were cut into smaller pieces, air dried at room temperature, and then pulverized into powder using a clean grinder. Aqueous root extract of ginger was made by macerating 2000 g of the ginger root in 12 liters of water for 72 h. It was then filtering using Whatman No. 1 filter paper to obtain a clear aqueous filtrate. The filtrate was concentrated using a water bath at low temperature to avoid heat destruction of active compounds. The yield was 8.6%. The concentrated extract was stored in a clean airtight container at refrigerated temperature until use. Before administration, the extract was reconstituted in distilled water to obtain the required dose of 600 mg/kg body weight (El-Bahr *et al.*, 2022).

Induction of diabetes

Diabetes was induced in the experimental rats using alloxan according to the method of Edo *et al.*, (2024). After administration of alloxan (150 mg/kg bw), fasting blood sugar levels were checked 24 to 48 hours later. Rats with fasting blood sugar levels above 7.0 mmol/L were considered diabetic and selected for the treatment phase of the study. Fasting blood sugar was measured using the glucose oxidase method.

Experimental design

The animals were divided into five groups containing five rats each.

Group 1: Normal control rats with normal fasting blood sugar levels.

Group 2: Diabetic untreated rats.

Group 3: Diabetic rats treated with aqueous ginger extract at 600 mg/kg body weight.

Group 4: Diabetic rats treated with aqueous ginger extract at 600 mg/kg body weight plus glibenclamide at 0.14 mg/kg body weight per day.

Group 5: Diabetic rats treated with glibenclamide only.

The treatment lasted for 28 days after diabetes induction. Fasting blood sugar was measured on day 0, day 14, and day 28. At the end of the treatment period, the rats were sacrificed, and the pancreas, liver, and kidneys were collected and processed for biochemical analysis.

Biochemical assays

Reduced glutathione was determined using the method of Jollow *et al.*, (1974), glutathione S transferase activity was determined according to Habig *et al.*, (1974), superoxide dismutase activity was determined using the method of Misra and Fridovich, (1972) while lipid peroxidation was assessed according to the method of Farombi *et al.*, (2000).

Statistical analysis

Data were expressed as mean $\pm$ standard deviation. Statistical analysis was performed using one way analysis of variance for comparison among groups, followed by Tukey's post hoc test for multiple comparisons. Differences was considered statistically significant at $p < 0.05$.

Results and Discussion

Effect of co-administration of aqueous ginger extract and Glibenclamide on fasting blood sugar levels in alloxan induced diabetes in rats

Table 1 shows that the normal control group maintained stable glucose levels throughout the study period. In comparison, the diabetic untreated group showed progressive hyperglycaemia, increasing from day 0 to day 14 and day 28. This confirms persistence of diabetes in the untreated rats and suggests that alloxan induction caused a sustained impairment of glucose regulation. The co-administered group on the other hand caused a sustained reduction in fasting blood sugar levels from day 0 to 14 and 28 when compared to control and either of the two intervention groups alone. Though the administration of ginger and glibenclamide reduced fasting blood sugar levels significantly compared to the untreated, the co-administered group was significantly more reduced.

Table 1: Effect of co-administration of aqueous ginger extract and glibenclamide on fasting blood sugar levels in alloxan induced diabetic rats

GROUP	FBS Day 0 (mmol/L)	FBS Day 14 (mmol/L)	FBS Day 28 (mmol/L)
Control	4.1±1.2	4.0±0.9	4.1±1.0
Untreated	7.3±1.1 ^a	7.9±0.3 ^a	8.2±1.3 ^a
Ginger	7.29±1.2 ^a	6.4±0.4 ^{abc}	5.8±0.5 ^{abc}
Ginger + Glibenclamide	7.36±0.9 ^a	3.7±0.4 ^b	2.3±0.9 ^{ac}
Glibenclamide	7.5±0.5 ^a	6.8±1.1 ^{ac}	5.4±0.3 ^{abc}

Values are presented as mean±SD. ^a values differ significantly compared to control. ^b values differ significantly compared to untreated group. ^c values differ significantly compared to Ginger + Glibenclamide group.

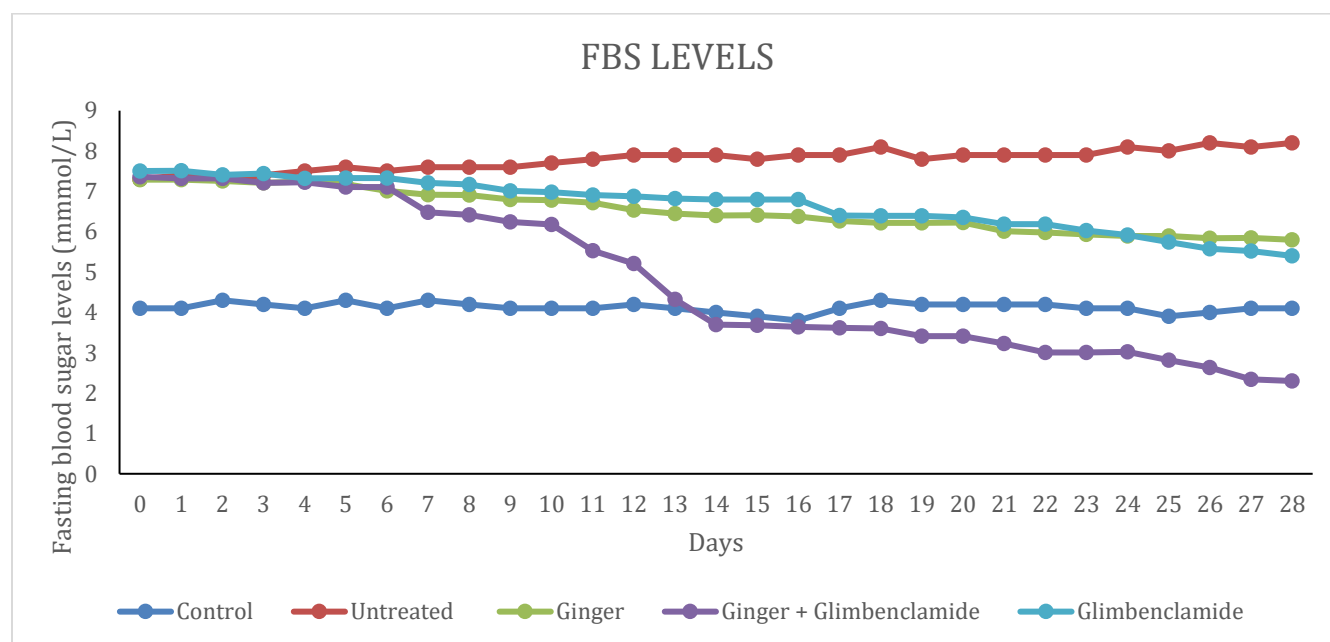


Figure 1: Effect of co-administration of aqueous ginger extract and glibenclamide on fasting blood sugar levels in alloxan induced diabetic rats

Effect of co-administration of aqueous ginger extract and Glibenclamide on pancreatic antioxidant and peroxidative markers in alloxan induced diabetes in rats

Table 2 shows marked oxidative stress in the pancreas of the untreated diabetic group. Pancreatic reduced glutathione, glutathione s transferase and super oxide dismutase decreased significantly in the untreated diabetic group compared to control. Though the administration of aqueous ginger extract and Glibenclamide individually improved the antioxidant status in rats significantly compared to control, the co-administration of the two had more significant effect on the GSH levels, GST and SOD activities. Lipid peroxidation increased significantly in the untreated group compared to control. Administration of aqueous extract of ginger and glibenclamide both reduced

the levels of peroxidation significantly compared to the untreated group. It was however observed that the highest effect was achieved in the co-administered group.

Table 2: Effect of co-administration of aqueous ginger extract and Glibenclamide on pancreatic antioxidant and peroxidative markers in alloxan induced diabetes in rats

GROUP	GSH (µg/ml)	GST (U/mg protein)	SOD (U/mg protein)	LPO (U/mg protein)
Control	7.64±0.21	8.51±0.02	2.41±0.32	3.65±0.23
Untreated	3.73±0.02 ^{ac}	4.61±0.03 ^{ac}	1.34±0.12 ^{ac}	6.21±0.03 ^{ac}
Ginger	6.68±0.02 ^{bc}	7.21±0.02 ^{bc}	2.21±0.32 ^{bc}	3.91±0.34 ^{bc}
Ginger + Glibenclamide	8.69±0.12 ^{ab}	9.99±0.32 ^{ab}	3.52±0.22 ^{ab}	2.18±0.06 ^{ab}
Glibenclamide	6.70±0.04 ^{abc}	7.42±0.41 ^{abc}	2.22±0.2 ^{bc}	3.96±0.22 ^{bc}

Values are presented as mean±SD. ^a values differ significantly compared to control. ^b values differ significantly compared to untreated group. ^c values differ significantly compared to Ginger + Glibenclamide group.

Effect of co-administration of aqueous ginger extract and Glibenclamide on liver antioxidant and peroxidative markers in alloxan induced diabetes in rats

Table 3 shows evidence of oxidative stress in untreated diabetic rats. Hepatic GSH, GST and SOD reduced significantly in the untreated group compared to control. Administration of aqueous ginger extract and Glibenclamide in their respective groups significantly increased the antioxidant enzymes compared to the untreated. The co-administered group had more significant effect on the antioxidant enzymes compared to the individual groups. Lipid peroxidation was significantly higher in the untreated group compared to control. The administration of aqueous ginger extract and Glibenclamide in their respective groups significantly reduced the levels of lipid peroxidation compared to the untreated. The co-administered group had more significant effect on the peroxidation levels compared to the individually administered groups.

Table 3: Effect of co-administration of aqueous ginger extract and Glibenclamide on liver antioxidant and peroxidative markers in alloxan induced diabetes in rats

GROUP	GSH (µg/ml)	GST (U/mg protein)	SOD (U/mg protein)	LPO (U/mg protein)
Control	8.68±0.23	8.72±0.32	2.21±0.11	3.21±0.33
Untreated	3.79±0.05 ^{ac}	4.52±0.12 ^{ac}	1.21±0.33 ^{ac}	5.89±0.01 ^{ac}
Ginger	6.76±0.04 ^{ab}	7.33±0.45 ^{ab}	1.72±0.22 ^{ab}	3.74±0.22 ^{ab}
Ginger + Glibenclamide	9.78±0.02 ^{ab}	9.62±0.16 ^{ab}	3.31±0.42 ^{ab}	4.12±0.42 ^{ab}
Glibenclamide	6.72±0.03 ^{abc}	7.21±0.61 ^{abc}	1.781±0.02 ^{abc}	3.592±0.21 ^{bc}

Values are presented as mean±SD. ^a values differ significantly compared to control. ^b values differ significantly compared to untreated group. ^c values differ significantly compared to Ginger + Glibenclamide group.

Effect of co-administration of aqueous ginger extract and Glibenclamide on kidney antioxidant and peroxidative markers in alloxan induced diabetes in rats

Table 4 shows that the untreated diabetic group showed reduced renal antioxidant defence and elevated lipid peroxidation. Kidney GSH, GST and SOD reduced significantly in the untreated group compared to control. Groups that received aqueous ginger extract and Glibenclamide separately increased the levels of GSH and activity of GST and SOD significantly compared to control. It was however observed that the group that was co-administered aqueous ginger extract and Glibenclamide had the highest effect on the antioxidant parameters. Lipid peroxidation was significantly higher in the untreated group, a trend that was reversed by administration of aqueous ginger extract and Glibenclamide in their respective groups. But the co-administered group had the most significant effect on the levels of lipid peroxidation.

Table 4: Effect of co-administration of aqueous ginger extract and Glibenclamide on kidney antioxidant and peroxidative markers in alloxan induced diabetes in rats

GROUP	GSH (µg/ml)	GST (U/mg protein)	SOD (U/mg protein)	LPO (U/mg protein)
Control	7.84±0.01	8.21±0.43	1.85±0.22	3.89±0.45
Untreated	4.23±0.03 ^{ac}	3.93±0.53 ^{ac}	1.18±0.03 ^{ac}	6.49±0.23 ^{ac}
Ginger	7.26±0.21 ^{abc}	7.44±0.34 ^{abc}	1.72±0.03 ^{bc}	4.32±0.21 ^{bc}
Ginger + Glibenclamide	8.98±0.03 ^{ab}	9.53±0.21 ^{ab}	2.81±0.02 ^{ab}	2.81±0.41 ^{ab}
Glibenclamide	6.98±0.22 ^{abc}	7.52±0.22 ^{abc}	1.69±0.42 ^{bc}	4.41±0.44 ^{bc}

Values are presented as mean±SD. ^a values differ significantly compared to control. ^b values differ significantly compared to untreated group. ^c values differ significantly compared to Ginger + Glibenclamide group.

Discussion

This study showed that alloxan induced diabetes produced sustained hyperglycaemia and oxidative stress in the untreated diabetic rats. This was evident in the progressive increase in fasting blood sugar from day 0 to day 28, together with reduced GSH, GST and SOD activities and increased lipid peroxidation in the pancreas, liver and kidney. These findings confirm that alloxan caused pancreatic beta cell injury and impaired glucose regulation, with associated oxidative damage in metabolically active organs (Eguchi *et al.*, 2021).

Treatment with aqueous ginger extract and glibenclamide separately improved fasting blood sugar and antioxidant status when compared with the untreated diabetic group. Ginger may have improved glycaemic control through its antioxidant phytochemicals, which help reduce oxidative injury and support glucose metabolism (Li *et al.*, 2022). Glibenclamide, on the other hand, most likely reduced blood glucose by stimulating insulin release from surviving pancreatic beta cells (Semwal *et al.*, 2021). The improvement observed in both individual treatment groups suggests that each agent had beneficial antidiabetic and antioxidant effects in the diabetic rats.

The combined administration of aqueous ginger extract and glibenclamide produced the greatest reduction in fasting blood sugar (Table 1). This indicates a possible synergistic effect between the two treatments. The result suggests that ginger may have enhanced the glucose lowering action of glibenclamide, possibly by reducing oxidative stress, preserving pancreatic function and improving the metabolic environment for insulin action (Siregar *et al.*, 2022). However, the very

low fasting blood sugar recorded in the combined treatment group also suggests a possible risk of excessive hypoglycaemia, which should be carefully considered in further studies.

The pancreatic antioxidant results further support the protective effect of the combined treatment. The untreated diabetic rats showed marked reductions in GSH, GST and SOD, with increased lipid peroxidation, indicating oxidative damage in pancreatic tissue. In contrast, the combined treatment produced the highest antioxidant enzyme activities and the lowest lipid peroxidation level in the pancreas. This suggests that the combination may have offered stronger protection against alloxan induced pancreatic oxidative injury than either ginger or glibenclamide alone.

A similar pattern was observed in the kidney, where the diabetic untreated group showed reduced antioxidant defence and elevated lipid peroxidation. The combined treatment produced the strongest improvement in renal GSH, GST and SOD, with marked reduction in lipid peroxidation. This finding is important because the kidney is highly vulnerable to diabetic oxidative stress, and improved antioxidant defence may help reduce the risk of diabetes related renal damage (Wang & Zhang, 2024).

In the liver, the untreated diabetic group also showed evidence of oxidative stress, as reflected by reduced GSH, GST and SOD and increased lipid peroxidation. The combined treatment improved hepatic antioxidant enzyme activities more than the individual treatments. However, the lipid peroxidation value in the combined treatment group was lower than that of the untreated group but not lower than the ginger only and glibenclamide only groups. This suggests that while the combination improved hepatic antioxidant defence, its effect on hepatic lipid peroxidation was not as strong as observed in the pancreas and kidney.

Generally, the findings from this research indicate that co administration of aqueous ginger extract and glibenclamide produced better glycaemic control and stronger antioxidant defence than either treatment alone in alloxan induced diabetic rats. This is in perfect agreement with the studies of Nasir *et al.*, (2022) where it was demonstrated that the co-administration of unripe plantain and Glibenclamide led to better glycemic control. The results support the possible complementary role of ginger as an adjunct to conventional antidiabetic therapy. However, the excessive reduction in fasting blood sugar in the combined treatment group highlights the need for dose optimization, variation of study duration, safety evaluation and further studies before such a combination can be considered clinically relevant.

Conclusion

This study demonstrated that aqueous ginger extract and glibenclamide improved glycaemic control and antioxidant defence in alloxan induced diabetic Wistar rats. While both treatments showed beneficial effects when administered separately, their combined administration produced a stronger reduction in fasting blood sugar and greater enhancement of antioxidant markers in the pancreas, liver and kidney. The reduction in lipid peroxidation also suggests that the combination may protect vital organs against diabetes induced oxidative damage. These findings indicate that aqueous ginger extract may potentiate the antidiabetic and antioxidant effects of glibenclamide. However, the very low fasting blood sugar observed in the combined treatment group suggests a possible risk of hypoglycaemia. Therefore, further studies are recommended to determine the safest effective dose, clarify the mechanism of interaction and assess the long term safety of combining ginger extract with glibenclamide.

Conflict of interest

The authors have no conflict of interest.

References

- Ayustaningwarno, F., Anjani, G., Ayu, A. M., & Fogliano, V. (2024). A critical review of Ginger's (*Zingiber officinale*) antioxidant, anti-inflammatory, and immunomodulatory activities. *Frontiers in nutrition*, 11, 1364836.
- Dinić, S., Arambašić Jovanović, J., Uskoković, A., Mihailović, M., Grdović, N., Tolić, A., ... & Vidaković, M. (2022). Oxidative stress-mediated beta cell death and dysfunction as a target for diabetes management. *Frontiers in endocrinology*, 13, 1006376.
- Ebadi, A. G. (2025). Synergistic approaches in diabetes management: The role of anti-diabetic drugs and herbal medicine in therapeutic strategies. *Nepal Journal Of Medical Sciences*, 10(2).
- Edo, G. I., Jikah, A. N., Onoharigho, F. O., Akpogheli, P. O., Agbo, J. J., Ekokotu, H. A., ... & Owheruo, J. O. (2024). The ameliorative effects of *Vernonia amygdalina* extract on superoxide dismutase and glutathione s-transferase on alloxan induced diabetes on male Wistar rats. *Food Chemistry Advances*, 4, 100620.
- Eguchi, N., Vaziri, N. D., Dafoe, D. C., & Ichii, H. (2021). The role of oxidative stress in pancreatic β cell dysfunction in diabetes. *International journal of molecular sciences*, 22(4), 1509.
- El-Bahr, S. M., Elzoghby, R. R., Alfattah, M. A., Kandeel, M., & Hamouda, A. F. (2022). Aqueous Ginger (*Zingiber officinale*) Extract Ameliorates the Harmful Effects of High-Dose Lornoxicam in Albino Male Rats. *BioMed Research International*, 2022(1), 1546734.
- Engwa, G. A., Nweke, F. N., & Nkeh-Chungag, B. N. (2022). Free radicals, oxidative stress-related diseases and antioxidant supplementation. *Alternative Therapies in Health & Medicine*, 28(1).
- Farombi, E. O., Tahnteng, J. G., Agboola, A. O., Nwankwo, J. O., & Emerole, G. O. (2000). Chemoprevention of 2-acetylaminofluorene-induced hepatotoxicity and lipid peroxidation in rats by kolaviron—a *Garcinia kola* seed extract. *Food and Chemical Toxicology*, 38(6), 535-541.
- González, P., Lozano, P., Ros, G., & Solano, F. (2023). Hyperglycemia and oxidative stress: an integral, updated and critical overview of their metabolic interconnections. *International journal of molecular sciences*, 24(11), 9352.
- Habig, W. H., Pabst, M. J., & Jakoby, W. B. (1974). Glutathione S-transferases: the first enzymatic step in mercapturic acid formation. *Journal of biological Chemistry*, 249(22), 7130-7139.
- Jadon, A. S., Kaushik, M. P., Anitha, K., Bhatt, S., Bhadauriya, P., & Sharma, M. (2024). Types of diabetes mellitus, mechanism of insulin resistance and associated complications. In *Biochemical immunology of diabetes and associated complications* (pp. 1-18). Academic Press.
- Jollow, D. J., Mitchell, J. R., Zampaglione, N. A., & Gillette, E. J. (1974). Bromobenzene-induced liver necrosis. Protective role of glutathione and evidence for 3, 4-bromobenzene oxide as the hepatotoxic metabolite. *Pharmacology*, 11(3), 151-169.
- Li, H., Rafie, R., Xu, Z., & Siddiqui, R. A. (2022). Phytochemical profile and anti-oxidation activity changes during ginger (*Zingiber officinale*) harvest: Baby ginger attenuates lipid



- accumulation and ameliorates glucose uptake in HepG2 cells. *Food Science & Nutrition*, 10(1), 133-144.
- Longkumer, S., Jamir, A., Kechu, M., Ezung, S., & Pankaj, P. P. (2021). Alloxan monohydrate induced diabetes: A comprehensive review. *Sciences*, 1(1), 1-9.
- Nasir, A., Ansari, A. P., Rafeeqi, T. A., Goswami, P., Wadud, A., Akbar, S., & Ansari, H. (2022). Anti-diabetic potential of 'Safūf-i-Dhayābītus' as standalone and as an adjuvant with glibenclamide in streptozotocin-induced diabetic rats. *Phytomedicine Plus*, 2(1), 100218.
- Rostamkhani, H., Veisi, P., Niknafs, B., Jafarabadi, M. A., & Ghoreishi, Z. (2023). The effect of zingiber officinale on prooxidant-antioxidant balance and glycemic control in diabetic patients with ESRD undergoing hemodialysis: a double-blind randomized control trial. *BMC Complementary Medicine and Therapies*, 23(1), 52.
- Semwal, D. K., Kumar, A., Aswal, S., Chauhan, A., & Semwal, R. B. (2021). Protective and therapeutic effects of natural products against diabetes mellitus via regenerating pancreatic β -cells and restoring their dysfunction. *Phytotherapy Research*, 35(3), 1218-1229.
- Siregar, R. S., Hadiguna, R. A., Kamil, I., Nazir, N., & Nofialdi, N. (2022). Ginger (*Zingiber officinale* R.) as a Potent Medicinal Plant for the Prevention and Treatment of Diabetes Mellitus: A Review. *Tropical Journal of Natural Product Research*, 6(4).
- Siregar, R. S., Hadiguna, R. A., Kamil, I., Nazir, N., & Nofialdi, N. (2022). Ginger (*Zingiber officinale* R.) as a Potent Medicinal Plant for the Prevention and Treatment of Diabetes Mellitus: A Review. *Tropical Journal of Natural Product Research*, 6(4).
- Tomlinson, B., Patil, N. G., Fok, M., Chan, P., & Lam, C. W. K. (2022). The role of sulfonylureas in the treatment of type 2 diabetes. *Expert Opinion on Pharmacotherapy*, 23(3), 387-403.
- Wang, N., & Zhang, C. (2024). Oxidative stress: a culprit in the progression of diabetic kidney disease. *Antioxidants*, 13(4), 455.