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Modulation of Insulin Resistance and β-Cell Function by *Momordica charantia*

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ABSTRACT

Type-2 diabetes mellitus (T2DM) is characterized by insulin resistance and progressive pancreatic β-cell dysfunction. Strategies that improve insulin sensitivity while preserving β-cell function are essential for optimal metabolic control. *Momordica charantia* has been widely used as an antidiabetic agent; however, evidence regarding its effects on insulin resistance and β-cell function based on HOMA indices remains limited.

This study aimed to evaluate the effects of *Momordica charantia* on insulin resistance and pancreatic β-cell secretory capacity in a T2DM rat model using HOMA-IR and HOMA-β parameters. An experimental laboratory study with a post-test only control group design was conducted using 36 male Wistar rats randomly assigned into six groups (n = 6). T2DM was induced using the streptozotocin–nicotinamide protocol. Treatment groups received oral *Momordica charantia* extract (75, 150, and 300 mg/kg body weight), while a comparator group received vildagliptin. Fasting blood glucose and insulin levels were measured, and HOMA indices were calculated. Data were analyzed using one-way ANOVA and Kruskal–Wallis tests.

Administration of *Momordica charantia* significantly reduced HOMA-IR and increased HOMA-β values ($p < 0.05$), indicating improved insulin sensitivity and β-cell function. These findings support the potential role of *M. charantia* as a herbal-based adjunctive agent in T2DM management.

Keywords: β-cell function; HOMA-β; HOMA-IR; insulin resistance; Momordica charantia; type-2 diabetes mellitus

INTRODUCTION

Type-2 diabetes mellitus (T2DM) is a chronic metabolic disorder characterized by peripheral insulin resistance and a progressive decline in pancreatic β-cell secretory capacity. In the early stages of the disease, pancreatic β-cells compensate for insulin resistance by increasing insulin secretion; however, prolonged metabolic stress ultimately leads to β-cell dysfunction and impaired glucose homeostasis (Efird, 2014;

Richter et al., 2023). This dual pathophysiology highlights the importance of therapeutic strategies that not only reduce insulin resistance but also preserve or restore β-cell function.

The Homeostatic Model Assessment indices, HOMA-IR and HOMA-β, are widely used to evaluate insulin resistance and pancreatic β-cell secretory capacity. HOMA-IR reflects the degree of peripheral insulin resistance, whereas HOMA-β represents the ability of pancreatic β-cells to secrete insulin in response to fasting glucose levels. The combined evaluation of these indices provides a more integrated assessment of metabolic status in T2DM compared to conventional glycemic parameters alone (Kim et al., 2023; Mkhize et al., 2025a).

Momordica charantia (bitter melon) has long been utilized in traditional medicine as an antidiabetic agent. Previous studies have demonstrated that *M. charantia* contains various bioactive compounds, including charantin, polypeptide-P, flavonoids, and saponins, which contribute to glucose metabolism regulation and insulin signaling pathways (Joseph & Jini, 2013; Z. Liu, 2021; Oyelere et al., 2022). In addition to its hypoglycemic effects, *M. charantia* has been reported to exert antioxidant and cytoprotective activities that may protect pancreatic β-cells from metabolic stress–induced damage (Salim, 2025; Shimada et al., 2022).

Several experimental and clinical studies have suggested that *M. charantia* may improve glycemic control and insulin sensitivity (Kim et al., 2023; Mes et al., 2025a; Mkhize et al., 2025b). Other studies have also indicated its potential role in enhancing β-cell function and insulin secretion, including through incretin-related mechanisms and cellular protection pathways (ALI et al., 2022; Deora & Venkataraman, 2023; Romdhoni et al., 2025). However, most of these studies primarily rely on conventional glycemic markers and do not comprehensively assess the simultaneous interaction between insulin resistance and β-cell secretory capacity.

Therefore, a clear gap remains in the literature regarding the integrated evaluation of *Momordica charantia* effects on both insulin resistance and pancreatic β-cell function using HOMA-based indices, particularly in well-established type-2 diabetes mellitus experimental models. Addressing this gap is essential to better understand the pharmacodynamic role of *M. charantia* as a metabolic modulator rather than solely a glucose-lowering agent.

The novelty of this study lies in its integrative approach, which simultaneously evaluates insulin resistance and pancreatic β-cell secretory capacity using HOMA-IR and HOMA-β indices in a streptozotocin–nicotinamide-induced T2DM rat model. In addition, this study examines the dose-dependent effects of *M. charantia* extract, providing further insight into its pharmacological profile and therapeutic potential. Therefore, this study aimed to evaluate the effects of *Momordica charantia* on insulin resistance and pancreatic β-cell secretory capacity in a rat model of type-2 diabetes mellitus using HOMA-IR and HOMA-β parameters.

Ethical Approval

All experimental procedures involving animals were conducted in accordance with institutional guidelines for animal care and use and complied with internationally accepted principles for laboratory animal research, no. 91/UN27.06.11/KEP/EC/2023.

Experimental Animals

Healthy male Wistar rats (Rattus norvegicus), weighing 180–220 g at baseline, were used in this study. Only male animals were selected to minimize hormonal variability. Animals were acclimatized for 7 days prior to the experiment and housed under standard laboratory conditions (12-hour light/dark cycle, controlled room temperature), with free access to standard chow and water (*ad libitum*).

Sample Size and Group Allocation

A total of 36 rats were randomly allocated into six experimental groups (n = 6 per group). Randomization was performed to reduce selection bias. Each animal was assigned to only one experimental group.

Experimental Groups

The experimental groups were defined as follows:

1. Normal Control Group

   Rats received standard chow without diabetes induction.

2. Diabetic Control Group

   Rats received standard chow and were induced with diabetes using the streptozotocin–nicotinamide (STZ–NA) protocol.

3. Negative Control Group (Drug Comparator)

   Rats received standard chow, were induced with STZ–NA, and were treated with vildagliptin at a dose of 0.9 mg/day.

4. Treatment Group 1

   Rats received standard chow, were induced with STZ–NA, and were administered *Momordica charantia* fruit extract at a dose of 75 mg/kg body weight.

5. Treatment Group 2

   Rats received standard chow, were induced with STZ–NA, and were administered *Momordica charantia* fruit extract at a dose of 150 mg/kg body weight.

6. Treatment Group 3

   Rats received standard chow, were induced with STZ–NA, and were administered *Momordica charantia* fruit extract at a dose of 300 mg/kg body weight.

This grouping strategy was designed to assess the dose-dependent effects of *Momordica charantia* extract on metabolic parameters.

Induction of Type-2 Diabetes Mellitus

Type-2 diabetes mellitus was induced using the streptozotocin–nicotinamide (STZ–NA) method. Rats were initially administered nicotinamide at a dose of 230 mg/kg body weight via intraperitoneal injection. Twenty minutes later, streptozotocin (STZ) was administered intraperitoneally at a dose of 65 mg/kg body weight (Romdhoni et al., 2025).

This protocol was selected to establish a T2DM model characterized by hyperglycemia, insulin resistance, and partial pancreatic β-cell damage, thereby closely mimicking the pathophysiology of human T2DM.

Treatment Administration

Momordica charantia fruit extract was administered orally at the assigned doses for each treatment group throughout the experimental period. The negative control group received vildagliptin as a pharmacological comparator, while the diabetic control group did not receive any antidiabetic treatment.

Outcome Measures

At the end of the treatment period, fasting blood glucose and fasting insulin levels were measured. Insulin resistance and pancreatic β-cell secretory capacity were assessed by calculating HOMA-IR and HOMA-β indices using standard formulas.

Statistical Analysis

Data distribution was assessed using the Shapiro–Wilk normality test. HOMA-IR values were analyzed using one-way analysis of variance (ANOVA) as they met the assumptions of normality, whereas HOMA-β values were analyzed using the Kruskal–Wallis test due to non-normal distribution. Statistical significance was defined as a p-value < 0.05.

RESULTS AND DISCUSSION

This study demonstrated significant differences in HOMA-IR values among the experimental groups. The diabetic control group exhibited the highest HOMA-IR values, whereas the normal control group showed the lowest values. Rats treated with *Momordica charantia* exhibited lower HOMA-IR values compared to the diabetic control group, indicating an improvement in insulin sensitivity.

Analysis of HOMA-β values also revealed significant differences among groups. The diabetic control group showed the lowest HOMA-β values, while the treatment groups exhibited increased HOMA-β values, although these values did not reach those observed in the normal control group.

Fasting Blood Glucose and Insulin Levels

The mean fasting blood glucose (FBG) and insulin levels for each experimental group are presented in Table 1. The normal control group demonstrated the lowest fasting blood glucose levels, whereas the untreated diabetic group exhibited the highest levels. The treatment groups showed lower variability in fasting blood glucose levels compared with the diabetic control group. Fasting insulin levels were relatively comparable across groups, with only minor variations observed among the experimental groups.

Table 1. Mean fasting blood glucose and insulin levels.

Group	**FBG** (mg/dL) (Mean ± SD)	Insulin **Levels** (μIU/mL) (Mean ± SD)
I	132,00 ± 17,01	3,17 ± 0,23
II	454,00 ± 106,85	3,17 ± 0,24
III	214,00 ± 103,04	3,46 ± 0,34
IV	315,50 ± 121,19	3,45 ± 0,09
V	402,50 ± 158,38	2,97 ± 0,29
VI	291,00 ± 127,37	3,15 ± 0,43

Comparison of HOMA-IR Values among Groups

HOMA-IR was used to assess the degree of insulin resistance. The analysis demonstrated significant differences in HOMA-IR values among the experimental groups based on one-way analysis of variance (ANOVA) ($p < 0.001$).

The normal control group exhibited the lowest HOMA-IR values, whereas the untreated diabetic group showed the highest values. The *Momordica charantia*–treated groups demonstrated reduced HOMA-IR values compared with the diabetic control group.

Table 2. HOMA-IR values among experimental groups.

Group	HOMA-IR (Mean ± SD)
I	1,05 ± 0,20
II	3,47 ± 0,69
III	1,58 ± 0,93
IV	2,70 ± 0,99
V	3,05 ± 1,32
VI	2,38 ± 1,06

Statistical analysis:

One-way ANOVA, $p = 0.020$

Comparison of HOMA-β Values among Groups

HOMA-β was used to describe pancreatic β-cell function. Kruskal–Wallis analysis revealed significant differences in HOMA-β values among the experimental groups ($p < 0.001$).

The normal control group exhibited the highest HOMA-β values, whereas the untreated diabetic group showed the lowest values. The treatment groups demonstrated increased HOMA-β values compared with the diabetic control group, although these values remained lower than those of the normal control group.

Table 3. HOMA-β values among experimental groups.

Group	HOMA-β (Mean ± SD)
I	16,85 ± 3,30
II	2,84 ± 2,34
III	7,15 ± 3,91
IV	5,58 ± 2,68
V	3,68 ± 1,76
VI	5,24 ± 2,03

Statistical analysis:

Kruskal–Wallis test, $p = 0.004$

Overall, administration of *Momordica charantia* in a type-2 diabetes mellitus rat model resulted in decreased HOMA-IR values and increased HOMA-β values compared with the untreated diabetic group. These findings indicate an improvement in insulin sensitivity and pancreatic β-cell function in the treatment groups.

The present study demonstrated a significant reduction in HOMA-IR values in rats treated with *Momordica charantia*, indicating an improvement in insulin sensitivity in a type-2 diabetes mellitus (T2DM) model. This finding suggests that *M. charantia* is capable of modulating insulin resistance, a central pathophysiological feature of T2DM. The observed reduction in HOMA-IR aligns with previous reports describing the insulin-sensitizing effects of *M. charantia* in experimental models of diabetes(Garcia et al., 2023; Richter et al., 2023).

One of the proposed mechanisms underlying the insulin-sensitizing effect of *M. charantia* involves activation of the AMP-activated protein kinase (AMPK) pathway. AMPK plays a critical role in regulating

cellular energy homeostasis by enhancing glucose uptake and fatty acid oxidation while suppressing hepatic gluconeogenesis. Activation of AMPK by bioactive compounds derived from *M. charantia* has been shown to improve peripheral insulin sensitivity, particularly in skeletal muscle and hepatic tissues (Chahrour et al., 2025; Richter et al., 2023; Zhao et al., 2024).

In addition to AMPK activation, experimental studies have demonstrated that *M. charantia* can modulate insulin signaling at the receptor and post-receptor levels. Bioactive constituents such as charantin and flavonoids have been reported to enhance the expression and phosphorylation of insulin receptor substrate-1 (IRS-1), thereby improving downstream insulin signal transduction (Y. Liu et al., 2021). Improved IRS-1 signaling contributes to enhanced glucose transporter translocation and glucose uptake, which may explain the reduced HOMA-IR values observed in the present study (ALI et al., 2022; Oyeleye et al., 2022).

Beyond improvements in insulin sensitivity, the present study also demonstrated a significant increase in HOMA-β values in *M. charantia*–treated groups compared with the untreated diabetic group. HOMA-β is widely used as a surrogate marker of pancreatic β-cell secretory capacity, and its increase suggests partial restoration or preservation of β-cell function. This finding is particularly relevant, as progressive β-cell dysfunction is a hallmark of T2DM progression (Peter et al., 2021).

The improvement in HOMA-β observed in this study may be attributed to a dual mechanism. First, improved insulin sensitivity reduces the secretory burden placed on pancreatic β-cells, thereby allowing functional recovery. Second, *M. charantia* has been reported to exert direct cytoprotective effects on β-cells through antioxidant and anti-apoptotic mechanisms, which may mitigate glucotoxicity- and lipotoxicity-induced β-cell damage (Fujii et al., 2019; Pinzon et al., 2024; Shimada et al., 2022).

Experimental evidence further suggests that *M. charantia* enhances intracellular ATP production in pancreatic β-cells, a critical step in glucose-stimulated insulin secretion. Increased ATP generation leads to closure of ATP-sensitive potassium channels, membrane depolarization, and subsequent calcium influx, ultimately triggering insulin exocytosis. This mechanism provides a plausible explanation for the increased HOMA-β values observed in the treatment groups (Deora & Venkataraman, 2023; Shimada et al., 2022).

The findings of this study are consistent with results from clinical and translational research. Randomized controlled trials and meta-analyses have reported trends toward reduced HOMA-IR and improved β-cell–related indices in individuals with diabetes or prediabetes receiving *M. charantia* supplementation, although the magnitude of effect varies depending on dosage, formulation, and treatment duration (Al-Musawi, 2022; Kim et al., 2023; Mes et al., 2025b; Mkhize et al., 2025a).

Variability in the reported efficacy of *M. charantia* across studies may be attributed to differences in extraction methods, bioactive compound concentrations, dosing regimens, and experimental models. These factors highlight the importance of standardized preparation and dosing strategies to achieve reproducible

metabolic effects, particularly when translating findings from animal models to clinical settings (Y. Liu et al., 2021; Z. Liu, 2021; Pu et al., 2021; Ramli et al., 2021).

Importantly, the simultaneous reduction in HOMA-IR and increase in HOMA-β observed in the present study indicates that *M. charantia* does not act solely as a glucose-lowering agent. Instead, it appears to function as a metabolic modulator that targets multiple components of T2DM pathophysiology. Such multitarget effects are characteristic of several plant-derived therapies and may offer advantages over monotherapeutic approaches that focus exclusively on glycemic control (Mkhize et al., 2025a; Richter et al., 2023).

Overall, the present findings support the potential role of *Momordica charantia* as an adjunctive therapeutic agent in T2DM management by improving insulin sensitivity and preserving pancreatic β-cell secretory capacity. While the results from this animal model are promising, further studies are warranted to elucidate precise molecular mechanisms, establish optimal dosing regimens, and confirm translational relevance in well-designed clinical trials.

CONCLUSION

Administration of Momordica charantia in a type-2 diabetes mellitus rat model reduced insulin resistance and enhanced pancreatic β-cell secretory capacity, as indicated by improvements in HOMA-IR and HOMA-β values. These findings strengthen the evidence that M. charantia has potential as a herbal-based adjunctive agent in the modulation of metabolic disturbances in type-2 diabetes mellitus, particularly through mechanisms involving improved insulin sensitivity and preservation of β-cell function.

However, several limitations should be considered. First, this study was conducted in an animal model, which may not fully represent the complexity of human T2DM. Second, the assessment of metabolic effects was limited to HOMA-based indices without direct evaluation of molecular pathways such as AMPK activation or β-cell histopathology. Third, variability in extract composition and the absence of phytochemical standardization may influence reproducibility and translational applicability. Therefore, further studies are warranted to investigate the underlying molecular mechanisms, optimize dosing strategies, and validate these findings in well-designed clinical trials.

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REFERENCE

ALI, A. M., MOQBEL, M. S., & AL-HIZAB, F. A. (2022). Effect of <i>Momordica charantia</i> on Insulin Immune-Reactive Pancreatic Beta Cells and Blood Glucose Levels in Streptozotocin-Induced Diabetic Rats. *Journal of Nutritional Science and Vitaminology*, *68*(5), 438–445. https://doi.org/10.3177/jnsv.68.438

Al-Musawi, J. F. H. (2022). efficacy of Momordica charantia L. (herbal agent) in treatment of type 1 diabetes mellitus in rats in comparison to insulin (animal model). *International Journal of Health Sciences*, 6061–6070. https://doi.org/10.53730/ijhs.v6ns3.7339

Chahrour, J. A., Abdel Baki, Z., El Badan, D., Nasser, G., Maresca, M., & Hijazi, A. (2025). Herbal Medicines in the Management of Diabetes Mellitus: Plants, Bioactive Compounds, and Mechanisms of Action. *Biomolecules*, *15*(12), 1674. https://doi.org/10.3390/biom15121674

Deora, N., & Venkataraman, K. (2023). A systematic review of medicinal plants and compounds for restoring pancreatic ß-cell mass and function in the management of diabetes mellitus. *Journal of Applied Pharmaceutical Science*, *13*(7), 55–72. https://doi.org/10.7324/JAPS.2023.130422

Efird, J. T. (2014). Potential for improved glycemic control with dietary Momordica charantia in patients with insulin resistance and pre-diabetes. In *International Journal of Environmental Research and Public Health* (Vol. 11, Number 2, pp. 2328–2345). https://doi.org/10.3390/ijerph110202328

Fujii, M., Murakami, Y., Karasawa, Y., Sumitomo, Y., Fujita, S., Koyama, M., Uda, S., Kubota, H., Inoue, H., Konishi, K., Oba, S., Ishii, S., & Kuroda, S. (2019). Logical design of oral glucose ingestion pattern minimizing blood glucose in humans. *Npj Systems Biology and Applications*, *5*(1). https://doi.org/10.1038/s41540-019-0108-1

Garcia, J. E., Mulrenin, I. R., Nguyen, A. B., Loop, M. S., Daubert, M. A., Urrutia, R., & Lee, C. R. (2023). Antihypertensive medication use during pregnancy in a real-world cohort of patients diagnosed with a hypertensive disorder of pregnancy. *Frontiers in Cardiovascular Medicine*, *10*. https://doi.org/10.3389/fcvm.2023.1225251

Joseph, B., & Jini, D. (2013). Antidiabetic effects of Momordica charantia (bitter melon) and its medicinal potency. *Asian Pacific Journal of Tropical Disease*, *3*(2), 93–102. https://doi.org/10.1016/S2222-1808(13)60052-3

Kim, B., Lee, H. S., Kim, H.-J., Lee, H., Lee, I., Ock, S., Kwon, S., Kang, S.-S., & Choi, Y. (2023). Momordica charantia (bitter melon) efficacy and safety on glucose metabolism in Korean prediabetes participants: a 12-week, randomized clinical study. *Food Science and Biotechnology*, *32*(5), 697–704. https://doi.org/10.1007/s10068-022-01214-9

Liu, Y., Mu, S., Chen, W., Liu, S., Cong, Y., Liu, J., & ... (2021). Saponins of Momordica charantia increase insulin secretion in INS-1 pancreatic β-cells via the PI3K/Akt/FoxO1 signaling pathway. *Endocrinología, Diabetes y …*. https://www.sciencedirect.com/science/article/pii/S253001802100069X

Liu, Z. (2021). The Effect of Momordica charantia in the Treatment of Diabetes Mellitus: A Review. In *Evidence-based Complementary and Alternative Medicine* (Vol. 2021). https://doi.org/10.1155/2021/3796265

Mes, J. J., van den Belt, M., van der Haar, S., Oosterink, E., Luijendijk, T., Manusama, K., van Dam, L., de Bie, T., Witkamp, R., & Esser, D. (2025a). Bitter gourd (Momordica charantia L.) supplementation for twelve weeks improves biomarkers of glucose homeostasis in a prediabetic population. *Journal of Ethnopharmacology*, *347*, 119756. https://doi.org/10.1016/j.jep.2025.119756

Mes, J. J., van den Belt, M., van der Haar, S., Oosterink, E., Luijendijk, T., Manusama, K., van Dam, L., de Bie, T., Witkamp, R., & Esser, D. (2025b). Bitter gourd (Momordica charantia L.) supplementation for twelve weeks improves biomarkers of glucose homeostasis in a prediabetic population. *Journal of Ethnopharmacology*, *347*, 119756. https://doi.org/https://doi.org/10.1016/j.jep.2025.119756

Mkhize, S. A. L., Phoswa, W. N., Ngubane, P. S., & Mokgalaboni, K. (2025a). Efficacy of Momordica charantia in glycaemic control and insulin resistance among patients with prediabetes and type 2 diabetes. A GRADE-adherent meta-analysis of randomised controlled trials. *Metabolism Open*, *28*, 100407. https://doi.org/10.1016/j.metop.2025.100407

Mkhize, S. A. L., Phoswa, W. N., Ngubane, P. S., & Mokgalaboni, K. (2025b). Efficacy of Momordica charantia in glycaemic control and insulin resistance among patients with prediabetes and type 2 diabetes. A GRADE-adherent meta-analysis of randomised controlled trials. *Metabolism Open*, *28*, 100407. https://doi.org/https://doi.org/10.1016/j.metop.2025.100407

Oyelere, S. F., Ajayi, O. H., Ayoade, T. E., Santana Pereira, G. B., Dayo Owoyemi, B. C., Ilesanmi, A. O., & Akinyemi, O. A. (2022). A detailed review on the phytochemical profiles and anti-diabetic mechanisms of Momordica charantia. *Heliyon*, *8*(4), e09253. https://doi.org/10.1016/j.heliyon.2022.e09253

Oyeleye, S. I., Olasehinde, T. A., Fasakin, O. W., Oboh, G., & ... (2022). … . and Momordica charantia L extracts improve memory function, attenuate cholinergic and purinergic dysfunction, and suppress oxidative stress in the brain of …. In *Phytomedicine Plus*. Elsevier. https://www.sciencedirect.com/science/article/pii/S2667031322000665

Peter, E. L., Nagendrappa, P. B., Hilonga, S., & ... (2021). Pharmacological reflection of plants traditionally used to manage diabetes mellitus in Tanzania. *Journal of* …. https://www.sciencedirect.com/science/article/pii/S0378874120336035

Pinzon, M. C. A. N. L., Letsoin, R. T. P., & Sugianto. (2024). The Challenges and Obstacles in Diagnosing Neuropathy in Patients With Diabetes. *Saintika Medika*, *20*(2), 153–163. https://doi.org/10.22219/sm.Vol20.SMUMM2.36581

Pu, L., Yang, C., Yu, L., Li, S., Liu, Y., Liu, X., & Lai, X. (2021). Tibetan Medicines for the Treatment of Diabetic Nephropathy. In *Evidence-based Complementary and Alternative Medicine* (Vol. 2021). Hindawi Limited. https://doi.org/10.1155/2021/7845848

Ramli, R., Didik Kurniawan, & Rahman, H. R. (2021). Prevention Of Type 2 Diabetes Mellitus Among Adolescents In Ternate City, Indonesia. *Saintika Medika*, *17*(2), 100–111. https://doi.org/10.22219/sm.Vol17.SMUMM2.15112

Richter, E., Geetha, T., Burnett, D., Broderick, T. L., & Babu, J. R. (2023). The Effects of Momordica charantia on Type 2 Diabetes Mellitus and Alzheimer's Disease. *International Journal of Molecular Sciences*, *24*(5), 4643. https://doi.org/10.3390/ijms24054643

Romdhoni, M. F., Doewes, M., Soetrisno, S., & Febrinasari, R. P. (2025). Antidiabetic Activity of Momordica charantia Extracts Through Incretin Pathway in Streptozotocin-Nicotinamide Induced Diabetic Rat Depends on Dose Differences. *Avicenna Journal of Medical Biotechnology*, *17*(1), 47–55. https://doi.org/10.18502/ajmb.v17i1.17677

Salim, A. (2025). The Effect of Bitter Melon Consumption on Blood Glucose Reduction: Chemical Overview and Mechanisms on the Pancreas. *JOURNAL OF MEDICAL AND CLINICAL CASE REPORTS*. https://doi.org/10.61615/JMCCR/2025/JULY027140717

Shimada, T., Kato, F., Dwijayanti, D. R., Nagata, T., Kinoshita, A., Okuyama, T., Nishizawa, M., & Mukai, E. (2022). Bitter melon fruit extract enhances intracellular ATP production and insulin secretion from rat pancreatic β-cells. *British Journal of Nutrition*, *127*(3), 377–383. https://doi.org/10.1017/S0007114521001082

Zhao, D., Luo, Z., Li, S., Liu, S., & Wang, C. (2024). Metabolomics Revealed the Effects of Momordica charantia L. Saponins on Diabetic Hyperglycemia and Wound Healing in Mice. *Foods*, *13*(19). https://doi.org/10.3390/foods13193163