University of Thi-Qar Journal of agricultural research

Thi-Qar Journal of agricultural research

ISSN Onlin:2708 -9347, ISSN Print: 2708 -9339 Volume 15, Issue 1 (2026)

https://iasj.rdd.edu.iq/journals/journal/issue/20226 *https://doi.org/10.54174/utjagr.v13ii 46.*

The Anti-Diabetic Physiological Mechanisms of Medicinal Plant: A Review

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I. Abstract

Diabetes leads to an increase in blood sugar levels, which in turn affects vital organs in the body such as the heart, kidneys, nerves, and blood vessels. The number of people affected by diabetes is noticeably increasing worldwide, which in turn reflects the urgent need to use medicinal plants as an alternative treatment to chemical drugs, as they are safe, inexpensive, and little side effects. Many medicinal plants possess anti-diabetic properties through their bioactive compounds, which have physiological mechanisms capable of lowering blood sugar, including the following mechanisms. chiefly by promoting both insulin secretion and sensitivity, decreasing glucose absorption, and inhibiting oxidative stress. The Intent of this study is to appraisal the physiological mechanisms of plants displaying antidiabetic features**.**

Key Words : *Diabetes Mellitus, Physiological Mechanisms, Glucose, Medicinal Plants, Insulin.*

II. Introduction

Diabetes mellitus is a chronic metabolic sickness that happens once the pancreas is incapable to create appropriate insulin, or the body incapable to consume it sufficiently (Shakeel et al., 2018). Diabetes mellitus is ordered into numerous forms, with the two principal types being type 1 plus type 2, type 1 diabetes mellitus, usually mentioned as insulin-dependent diabetes, caused by an autoimmune ruin of pancreatic β- cells at the islets of Langerhans causing a complete insulin insufficiency while type 2 diabetes mellitus usually mentioned as non-insulin-dependent diabetes, is mainly known by an insulin resistance owing to faults in insulin receptor, mostly at the tyrosine kinase level, other forms of diabetes comprise gestational diabetes mellitus a form that happens during pregnancy and monogenic diabetes, a form that associated with genetic defects in β-cell function (Bastaki, 2005; Dey, 2023) Figure 1. Insulin resistance is the hallmarks of type 2 diabetes mellitus, which can cause unrelenting hyperglycemia with associated outcomes comprise nephropathy, neuropathy, retinopathy plus cardiovascular disease (Ayenew et al., 2026). Insulin, is an anabolic hormone, shows a vital role in the management the metabolism of carbohydrates, lipids, and protein, disturbances in insulin action have general consequences on the whole metabolic homeostasis (Campbell and Newgard, 2021). Weakened glucose metabolism as well as disorder of the insulin signaling path led to type 2 diabetes mellitus, the condition is linked to insulin resistance plus poor insulin sensitivity in the muscle, liver cells and adipose tissue.

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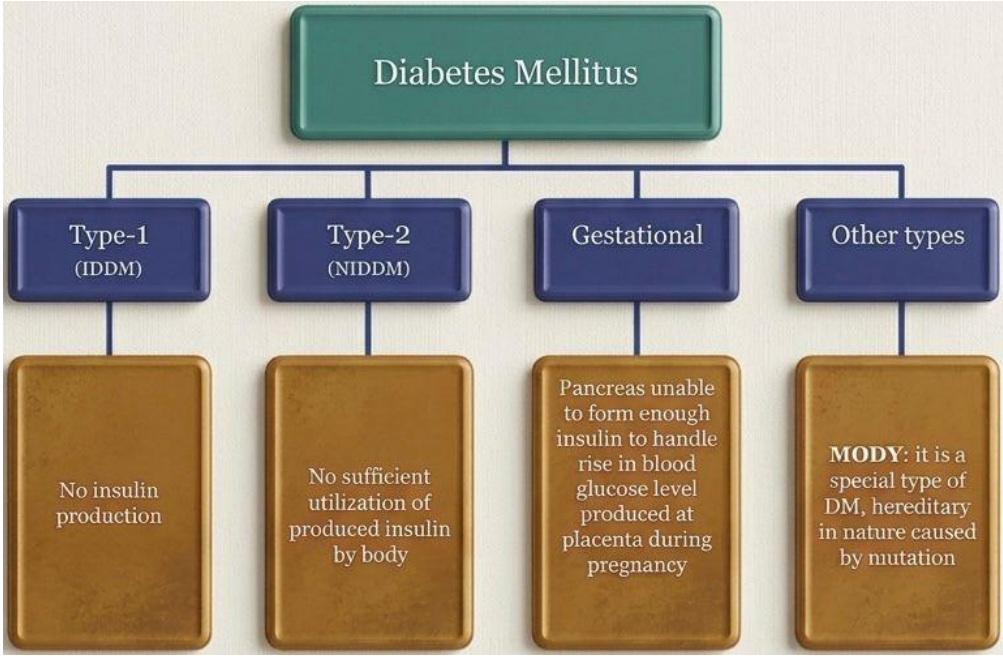

Figure 1: Classification of Diabetes Mellitus

To sustain steady blood glucose concentration, many human organs, comprising the pancreas, liver, adipose plus muscle tissues and intestine, with numerous hormones as well as neuropeptides, cooperate, the pancreas shows a vital role in the homeostasis of glucose via discharging insulin hormone plus its antagonist glucagon (Gowd etal., 2017), the enlarged amount of glucose is detected by the pancreatic beta cells and then glucose entry to the body cells through GLUT2, a transporter of insulin. Glucose prompts the releasing of insulin from beta cells thru the closing of ATP-sense potassium canals and initiation of voltage-gated calcium canals (Yaribeygi et al., 2019) as seen in (figure 2). The beta cell in the pancreas discharges extra insulin in reply to raised blood glucose concentration, but, this may lead to hyperinsulinemia because of insulin resistance, gradually hyperinsulinemia decreases beta cell activities which decreases insulin creation, causing hyperglycemia (Hegde et al.,2019). The most important hazard issues for increasing diabetes plus its ramifications are advancing age, chronic inflammation, ethnicity, obesity, incorrect eating habits, inactive lifestyle and instabilities in cellular redox equilibrium such as reductive as well as oxidative stress (Chakraborty and Sengupta, 2020; Tegegne et al., 2024).

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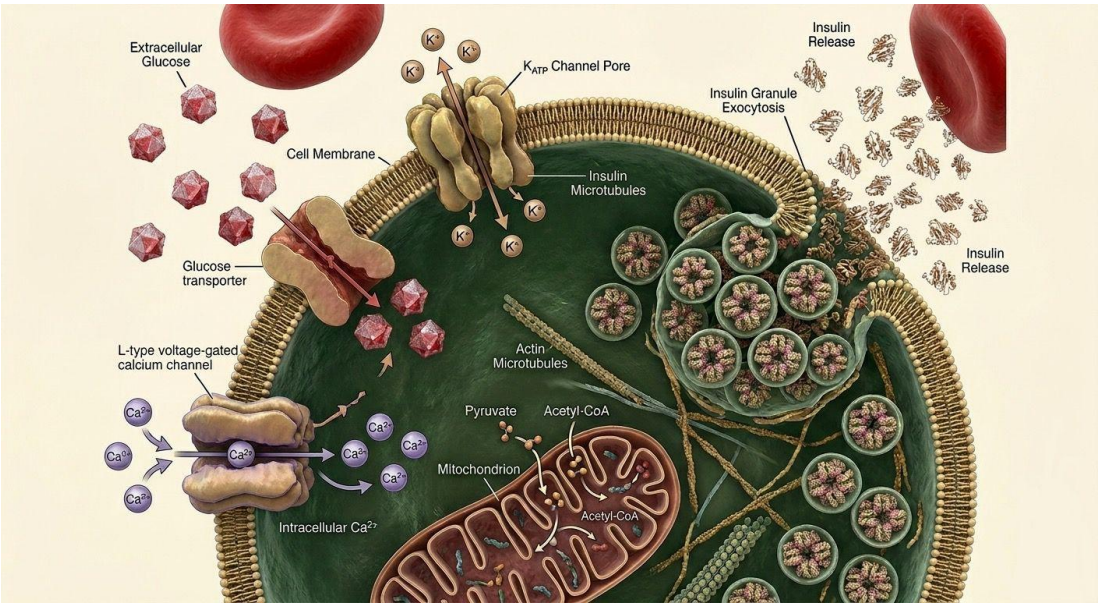

Figure 2: Mechanism of Insulin Secretion

Medical plants used in lowering Glucose levels

Medicinal plants has been utilized economically all over the world to avert or manage diabetes, many curative plants have showed hypoglycemic roles and are progressively utilized together with usual antidiabetic treatments, their physiological mechanisms comprise improving glucose acceptance by adipose plus muscle tissues, preventing glucose uptake from intestine, and hindering glucose creation from liver (Salleh et al., 2021; Hui et al., 2009) as seen in Figure 3.. Many phytochemicals that possess anti-hyperglycemic features found in curative plants have been explored according to the alterations in their chemical constitutes and they categorized as main groups such as alkaloids, terpenes, aromatic acids, flavonoids, coumarins, essential oils, carotenoids, organic acid, glycosides and phenols (Velu et al, 2018; Gonfa et al., 2021) The curative plants are usually safer, further cheap, and extra manageable comparing to artificial medicines, with less negative consequences (Mahmoud et al., 2024) . The medical plants can lower glucose concentration in the blood via the following mechanisms.

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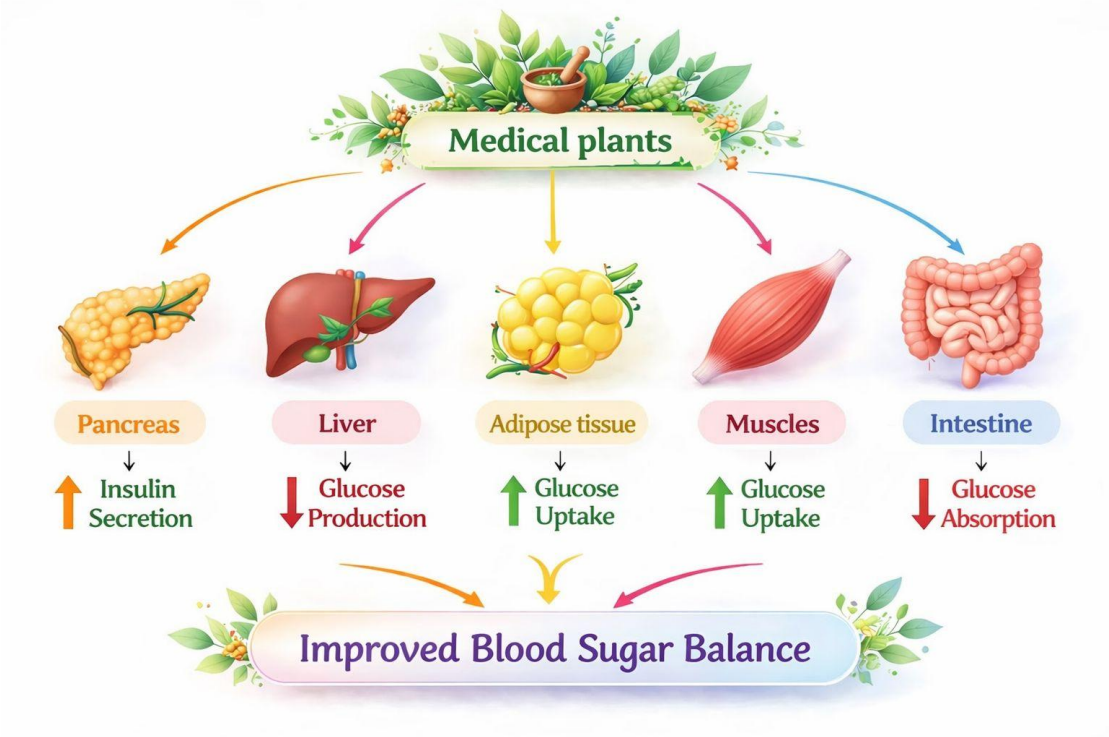

Figure 3: The Glucose Lowering Physiological Mechanisms of Medicinal Plants

1- Insulin release and peripheral sensitivity:

Many curative plants rise the human ability to manage blood glucose concentrations via prompting the pancreatic beta cells to secrete insulin (Negahdari, 2023). Many other plants possess hypoglycemic roles by inducing insulin responsiveness via promoting the GLUT4 protein expression and stimulating glucose acceptance initiated a lessening in blood glucose concentration such as *Andrographis paniculata* (Hayati and Hidayat, 2020), *Bambusa vulgaris* (Kumar and Mythili, 2022) and *Tamarindus indica* (Bhadoriya et al., 2018). Many plants enable glucose absorption by rising insulin responsiveness in the liver, muscles plus adipose tissue via blocking the ATP sense potassium canal, working on the Ca^{2+} canals, while another plant can lessen insulin breakdown by hindering insulinase or via owning cAMP phosphodiesterase suppressive action (Prabhakar and Doble, 2008) such as *Achillea millefollium* (Chávez-Silva et al., 2018). Other plant can activate the peroxisome proliferator-activated receptor gamma (PPARγ) and created the GLUT4 receptor accountable for glucose acceptance, which decreases blood glucose levels, so rising insulin sensitivity, decreasing insulin resistance, and blood glucose can be sufficiently managed (Fakhrozi et al., 2024).For instance, it has been demonstrated that many plants have the ability to increase insulin secretion such as *Clerodendrum paniculatum* (Varghese et al., 2021), *Azanza garckeana* (Lawal et al., 2022) and *Cinnamomum cassia* (Singh et al.,2018).

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2- Hindrance of Carbohydrate Hydrolyzing Enzymes:

Definite curative plants have mixtures that hinder the actin of carbohydrate-hydrolysing enzymes like alpha-glucosidase plus alpha-amylase (Ashagrie et al., 2025). Numerous studies ensure the possible of curative plants in blocking the actions of these enzymes (Adeleke et al., 2021). By hindering these enzymes, the hydrolysis of complex carbohydrates to simple one like glucose and the absorption of glucose is delayed, causing a decrease in postprandial hyperglycemia. Polyphenols associated to plants with anti-oxidative plus anti-hyperglycemic roles prompt their role by hindering carbohydrate metabolizing enzymes such as α-amylase plus α-glucosidase (Ademiluyi and Oboh, 2013). Plants belonging to *Liliaceae* family, comprising *Allium sativum* (garlic) plus *Allium cepa* (onion), have confirmed vital alpha-glucosidase restraining action, resulting in their anti-diabetic properties (Perez-Favila et al., 2019).

3- Oxidative stress reduction and inflammatory inhibition:

Elevated oxidative stress as well as inflammatory response are often connected to diabetes, these situations can deteriorate insulin resistance as well as beta-cell defect (Frimpong et al., 2024). Oxidative stress can effect diabetes both in insulin secretion as well as insulin role, it triggers NF-B plus JNK, IRS breakdown, defeats GLUT-4 expression and initiates inflammatory reaction (Ighodaro, 2018). Many plants can lessen mitochondrial impairment through directing sirtuin 1 activators (SIRT1) plus PPAR α (Kaikini et al., 2017). Throughout oxidative stress, reactive species promote an alteration and injury to cellular constituents comprising nucleic acids, and proteins, they also can activate many signaling ways resulting in the upregulation of many genes and consequential onset and development of diabetes complications (Sanchez et al., 2018). Many medical plants can reduce the oxidative stress disturbance due to their anti-inflammatory plus antioxidant properties such as *Allium sativum* (Ried et al, 2013), Azadirachta indica (Gupta et al., 2017) and *Moringa oleifera* (Gopalakrishnan et al., 2016). The ability of these plants to reduce oxidative stress is due to their bioactive materials that hunt free radicals, lesser inflammatory response, and protector in contradiction of oxidative injury comprise resveratrol, quercetin, plus curcumin (Boutaj et al., 2024).

4. Gut Microbiome Modification:

Prebiotics as well as other materials originate in many medicinal plants boost the growth of beneficial gut bacteria, improving gut health and circuitously enhancing glucose homeostasis, as gut microbiota is crucial for insulin sensitivity as well as glucose metabolism (Adhikari**,** 2021). Table 1: Shows some medical plants used in treat diabetes and their mechanisms of action.

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Table 1: Some Antidiabetic Medicinal Plants and their mechanisms of action.

Medicinal Plant	Mechanisms of Action
Olea europaea	-Displays anti-inflammatory plus antioxidant features. - enhancing insulin sensitivity and lessining blood sugar levels (Katan, 2004)
Allium Sativum	-Prompting the gene expression of caspase 3 plus caspase 9. -dropping IL-1β, IL-6, plus TNF-α level plus rising IFN-γ (Nani and Proverawati, 2021)
Momordica charantia	- Simulates insulin action - enhancing glucose uptake by skeletal muscles and lessining blood sugar levels -Inhibiting glucose absorption by the intestine (Ratwita et al., 2021)
Hibiscus sabdariffa	-Reducing the digestion of complex suger to simple sugar -Reducing glucose absorption (Kaur et al., 2021)
Zingiber Officinale	-Reducing insulin resistance (Mahluji et al., 2013)
Cinnamomum zeylanicum	-Promoting glucose metabolism in peripheral tissues. -Stimulating GLUT-4 expression. -Increasing plasma insulin (Medagama, 2015)
Berberis vulgaris	-Improving both insulin sensitivity and secretion -Stimulating the proliferation of pancreatic β-cells - Inhibiting key enzymes responsible for glucose regulation (Belwal et al., 2020).
Anacardium occidentale	-Enhancing beta- cells function -Lowering blood glucose (Olatunji et al., 2005).
Syzygium cumini	- enhancing insulin sensitivity - lessening carbohydrate absorption by the intestines (Sharma et al.,2010).
Gynostemma pentaphylium	- Improving insulin sensitivity • Increasing the GLUT4 expression (Xie et al., 2023)

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