The Journal of Applied Engineering and Agriculture Sciences
https://dergipark.org.tr/en/pub/umtd

REVIEW ARTICLE

A Review on the Plant-Based Bioactive Compounds Used in Treatment of Diabetes

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Submitted:28.05.2024
Revision Requested: 03.07.2024
Last Revision Received: 10.07.2024
Accepted: 11.07.2024

Citation: Döngel, A., Ertürk, H. (2024). A Review on the Plant-Based Bioactive Compounds Used in Treatment of Diabetes. *The Journal of Applied Engineering and Agriculture Sciences* 1(1), 1-9.

ABSTRACT

The purpose of this review is to provide a comprehensive overview of the current research on plant-based bioactive compounds used in the treatment of diabetes. By collecting and synthesizing articles on this topic, the review aims to identify the most promising compounds and their potential mechanisms of action in managing diabetes. Additionally, the review seeks to highlight gaps in the existing literature and areas for future research, guiding researchers towards new avenues of exploration. Ultimately, the goal of this review is to contribute to the growing body of knowledge on plant-based treatments for diabetes and to inform the development of new, more effective therapies for this chronic disease.

Keywords: Plant-based, diabetes, nano medicine

1. Introduction

Diabetes mellitus (DM) is characterized by significantly elevated blood glucose levels resulting from either insulin resistance or aberrant insulin production. In certain cases, both conditions can coexist (Hu, 2011). It is a silent killer that can lead to various pathophysiologydeveloping slowly or rapidly, such as peripheral arterial disease, coronary artery disease, stroke, retinopathy, neuropathy, and nephropathy (Qaseem, 2017; Khanra, 2017).

Diabetes is a chronic condition affecting the body's ability to regulate blood sugar levels. There are several types of diabetes, each with distinct characteristics and implications. Type 1 diabetes (T1DM) occurs when a person's pancreas is unable to generate insulin, which compromises their immune system and makes it difficult to control their blood sugar (Jain, 2021). This form of diabetes is one of the most prevalent endocrine and long-term metabolic disorders, accounting for two-thirds of all diabetes cases in children and adolescents. T1DM is acknowledged as a costly illness for both patients and society, associated with a greater risk of morbidity (Hashemipour, 2023).

In contrast, type 2 diabetes mellitus (T2DM) develops when the pancreas fails to generate enough insulin or the body's cells become resistant to insulin action (Taylor R. , 2012). This chronic metabolic disorder is caused by insulin resistance in peripheral insulin-sensitive organs and decreased insulin synthesis by pancreatic beta cells (Boussageon, 2018). The alarming rise in T2DM cases, particularly among overweight children before puberty and in developing nations, has become a significant concern. While patients with type 1 diabetes need insulin to control their blood glucose levels, those with type 2 diabetes can manage their condition with a healthy diet and regular exercise (Jain, 2021).

Additionally, gestational diabetes mellitus (GDM) is a form of glucose intolerance that emerges or is first identified during the second or third trimester of pregnancy. This condition is attributed to either pregnancy hormones or insufficient insulin levels, making it a prevalent metabolic disorder during pregnancy (Tran, 2020).

Understanding the different types of diabetes (Figure 1) and their symptoms is crucial for effective management and treatment. Each type requires a unique approach, emphasizing the importance of tailored healthcare strategies to improve

patient outcomes and reduce the burden on society.

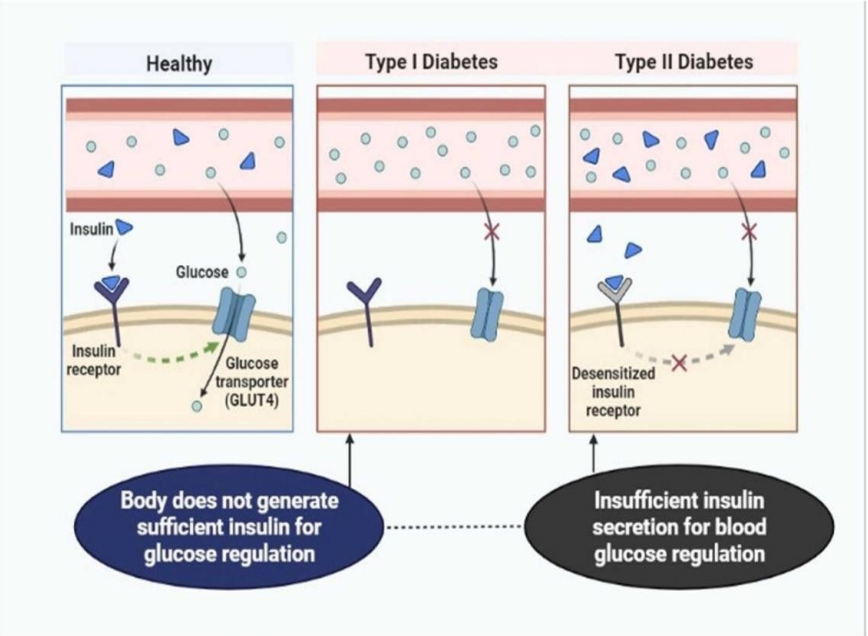

Figure 1. Various forms of diabetes and the signs associated with each (Rahman, 2022).

This review aims to collect and summarise the research findings on the effects of 'traditional' medicines using plants rather than modern medicine drugs. By examining the published articles and patents in this area, the methods used in diabetes treatment and their results were obtained. This analysis sheds light on the effectiveness of various plant-based therapies in managing diabetes, hopefully offering insights into potential alternative treatments and their implications for diabetes patient care.

2. Methods

2.1 Medicinal plant materials

Historically, medicinal plants have been used in a variety of ways across our healthcare systems, demonstrating their importance in preventing diabetes. The pharmaceutical and dietary supplement industries could undergo a radical shift as a result of the continuous research into novel active chemicals produced from plants. Dr. B. D. Vashistha has identified and authenticated *Euphorbia neriifolia Linn*. stems that were taken in November from Ambala, Haryana, India, as mentioned in this study (Devi, 2023). With approval voucher number KUK/BOT/IPS-36, these stems are formally recognized as true specimens and serve as a reminder of the value of plant materials in the continuous search for efficient diabetes mellitus therapies and preventive measures.

2.2 Extraction

Extracting bioactive components from natural product extracts is the first step in evaluating their biological activity. To obtain crude extracts, this procedure involves washing, drying, blending, and using various solvent systems. The use of suitable extraction techniques is essential to protect any bioactive components. The physical properties of the target compound determine the best solvent system to use: lipophilic molecules require dichloromethane, while hydrophilic compounds require methanol or another polar solvent. Selectivity is improved and solvent consumption is decreased with modern extraction techniques including solid-phase micro-extraction and supercritical fluid extraction. Bioactive components are effectively extracted using exhaustive extraction, which uses solvents with increasing polarity. The type of solvent used will determine how well bioactive compounds are identified; these criteria include polarity, mass transfer, toxicity, stability, and cost-effectiveness (Gothai, 2016).

2.3 *In vitro* antidiabetic agents and activities

One of the most popular strategies for controlling blood sugar levels involves blocking important enzymes. The following plants have demonstrated enzyme inhibitory activities that may be beneficial for treating diabetes and hyperglycaemia: *Abelmoschus moschatus, Alangium salvifolium, Boerhaavia diffusa, Capsicumfrutescens, Mangifera indica, Momordica charantia, Ocimum sanctum, Punica granatum, and Zingiber officinale* (Tadera, 2006).

The vital role of *α-amylase* in the human body is revealed by *in vitro* investigations that employ the *α-amylase* inhibition assay. *α-amylase* is an enzyme that breaks down starch into simpler sugars. Carbohydrate breakdown may assist diabetics in controlling their glycaemic index and insulin resistance. Macroptera of citrus Montr. The IC50 of methanol extract was (3.6380.190) mg/mL, whereas the IC50 of regular acarbose (ACB) was (0.9120.015) mg/mL. Similar to ACB, methanol extract significantly decreased *α- amylase* activity in a dose-dependent manner. Consequently, the extract of *C. macroptera* exhibits a slight anti-amylase effect. The ethanolic extract of *Andrographis paniculata* exhibited a concentration-dependent inhibition of *α-glucosidase* activity together with a modest inhibitory effect on *α-amylase*. The results indicated that *Andrographis paniculata* was a good option for treating type 2 diabetes.

By blocking the actions of *α-amylase* and *α-glucosidase* enzymes, ACB lowers hyperglycaemia. ACB is an oral medication used to manage type 2 diabetes. It works by inhibiting the activity of *alpha-glucosidase* enzymes, which are involved in carbohydrate digestion (PubChem Compound, 2024). However, because of its adverse effects, people with diabetes have poor treatment adherence when using ACB. Therefore, one of the challenges in treating T2DM is to lessen the negative effects caused by ACB without sacrificing its effectiveness (Narvaez, 2022).

In the study of Ugwor, 2022, the enzymatic assays, 500 μl of 20 mM sodium phosphate buffer (pH 6.9) containing 6 mM NaCl and pancreatic *α-amylase* (10 U/ml; Cat. No.: A3176) were incubated at 25 °C for 10 min., and 100 μL of various concentrations (20, 40, 60, 80, and 100 μg/ml) of 2-ethyl-1,4-dimethoxybenzene or acarbose (Cat. NO.: A8980). 500 μl of 1% starch solution, made in the same phosphate buffer, was added to start the reaction, which was then observed for 10 minutes at 540 nm. For the *α-glucosidase* experiment, 50 μL of 2-ethyl-1,4-dimethoxybenzene or acarbose (20, 40, 60, 80, or 100 μg/ml) was added to 100 μL of the *α-glucosidase* solution (Cat. No.: G5003), and the mixture was allowed to equilibrate for ten minutes at 25 °C. Following the addition of 50 μL of a 5 M p-nitrophenyl-α-D-glucopyranoside solution (in 0.1 M phosphate buffer; pH 6.9), the reaction was observed for five minutes at 405 nm. As previously mentioned, the HMGR inhibitory experiment was conducted using an assay kit (Sigma; Cat. No.: CS1090) that contained the catalytic domain of the human enzyme along with other reagents. In summary, the reaction mixture containing 400 μM NADPH and 400 μM HMG-CoA substrate was supplemented with 20 μL of the enzyme (0.5 mg/ml) and 10 μL of 2-ethyl-1,4-dimethoxybenzene or simvastatin (Cat. NO.: S6196). The final volume was 2 mL of 100 mM potassium phosphate buffer, pH 7.4 (containing 120 mM KCl, 1 mM EDTA, and 5 mM DTT). The rate of NADPH disappearance was monitored at 340 nm for 15 min. The blanks contained neither 2-ethyl-1,4-dimethoxybenzene nor reference drugs (Figure 2).

In the study that was carried out by Devi, 2023, to prepare a starch solution (1% w/v) for the starch hydrolysis test, one gram of starch was dissolved in 100 millilitres of 20 mM phosphate buffer (pH 6.9) and 6.7 mM sodium chloride. A 6.7 mM sodium chloride solution containing 100 ml of phosphate buffer (pH 6.9) was mixed with 27.5 mg of *α-amylase*. After adding plant extracts (25, 50, 100, 200, and 400 mg/ml) to 100 ml of *α-amylase*, the mixture was incubated for 20 minutes at 37°C. After adding a 10% starch solution to 100 milliliters of the reaction mixture, it was incubated for ten minutes at 37°C. Moreover, a boiling solution was supplemented with 1 g of 3,5- di-nitrosalicylic acid, 30 g of sodium potassium tartarate, and 20 ml of 2N-sodium hydroxide for a duration of 5 minutes. The volume reached 100 millilitres. The reaction mixture was diluted with 2.2 cc of water in order to assess absorbance. For every concentration, 200 µl of distilled water was used in place of the enzyme solution to create blank tubes. The standard was acarbose, an inhibitor of *α-amylase*. The same procedure was used to prepare an enzyme-free control that lacked the extract.

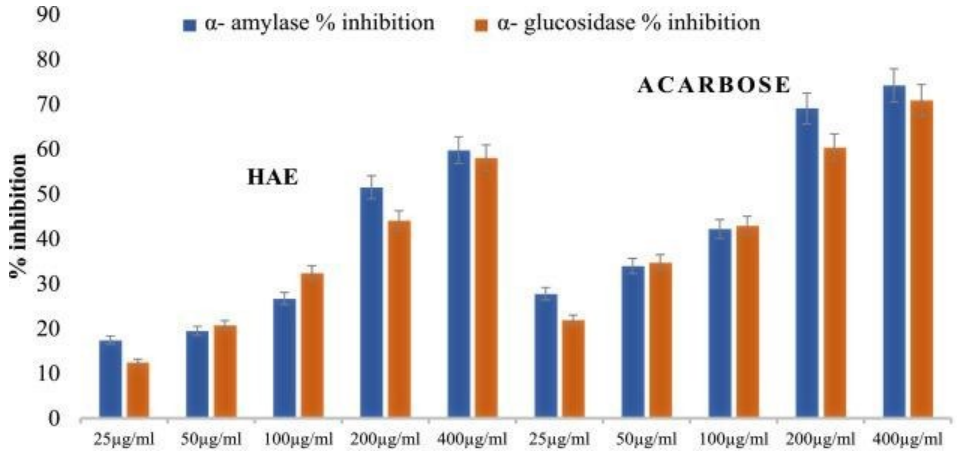

Figure 2. The percentage inhibition activity of α-amylase and α-glucosidase in HAE was measured. All measurements were recorded in triplicate and are presented as mean ± standard error of the mean (SEM) (Devi, 2023).

2.4 Pancreatic β-cells

Insulin resistance is frequently present in type 2 diabetes, which develops slowly and may go undiagnosed for years at a time. Initially, a compensatory rise in insulin secretion keeps blood glucose levels within the physiological range. The diagnosis of diabetes is postponed and prevented by this compensatory mechanism. Furthermore, prolonged stimulation of β cells results in their exhaustion and deterioration, which eventually causes inadequate insulin release. In this setting, numerous studies' findings indicate that temporarily resting β cells in people with chronically stimulated β cells enhances their secretory capacity and may postpone the development of overt diabetes (Szkudelski, 2011).

Reduced insulin secretion can result in persistent hyperglycaemia due to the increasing functional loss of β cells in the diabetic environment, which is driven by high lipids, high glucose, inflammatory mediators generated by adipose tissue, and endoplasmic reticulum stress (Butler A.E, 2003). Insulin resistance becomes apparent in the early stages of the natural progression before overt hyperglycaemia occurs. As long as pancreatic β cells release enough insulin to counteract the resistance, glucose levels remain relatively normal (Taylor S. Y., 2021). Numerous substances, including *curcumin, gymnemic acids, silymarin, quercetin, resveratrol,* and *berberine*, have been proposed as potential therapeutic agents for diabetes by restoring the functional mass of pancreatic β cells by various targets. For example, *resveratrol* and *curcumin* enhance the function of β cells by inhibiting *phosphodiesterases* in β cells, which suppresses pathogenic signaling processes. Another substance called *naringenin* prevents β cell loss by decreasing pro-apoptotic genes and restores β cell function by activating genes such as GLUT2, PDX1, Akt, insulin receptor substrate (IRS), B-cell lymphoma 2 (Bcl2), and heat shock protein (Hsp)70/90. Gallic acid inhibits apoptosis and restores insulin and PDX1 expression to avoid β cell dysfunction caused by excessive glucolipid levels (Bhattacharya, 2013).

The insulin gene produces insulin, a 51-amino-acid molecule with a molecular weight of 5.8 kDa. The precursor, preproinsulin (Wentworth, 1986), is 110 amino acids long. The synthesis involves several steps: folding, disulfide bond formation, signal peptide cleavage, and translocation across the rough endoplasmic reticulum (rER) membrane. After the ER, proinsulin is transported to the Golgi apparatus and then to immature secretory vesicles. Glucose metabolism is crucial for insulin synthesis, affecting insulin gene transcription and mRNA translation. Glucose infusion increases relative proinsulin mRNA levels and stabilizes insulin mRNA (Sharma, 1993).

The tissue and cell type-specific expression of the insulin gene is determined by its 5′-flanking region, located between −520 and +1 base pairs from the transcription start site (TSS). A conserved area between -350 bp and the TSS influences cell-type-specific insulin production. The primary insulin gene transcription enhancer region, responsible for cell-specific and glucose-regulated insulin gene expression, is located between -340 and +91 (Fu, 2013).

2.5 Nano formulations for the management of diabetes

Nanotechnology-based methods improve diabetes therapy control while lowering complications (Wilczewska, 2012). Drugs are effectively delivered to target sites using a variety of nano formulations with different structures, guaranteeing desired release patterns (McNeil, 2011). These formulations make use of nano carriers to enable medication administration via a variety of pathways (Florence, 2005). Adding the right ligands improves the drug's stability, systemic availability, and targeting. Nano carriers minimize the danger of adverse effects while enabling lower therapeutic doses and frequency of delivery. Hypoglycemic agent-designed nano formulations hold potential for better diabetes control (Chakraborty S., 2020).

Curcumin: Curcumin, the most active ingredient in turmeric, has drawn interest from scientists as a possible therapeutic agent for treating diabetic complications and experimental diabetes. (Zhang, 2013) A viable strategy to improve *curcumin's* solubility, stability, bioavailability, and therapeutic efficacy as an antidiabetic drug (Rathore, 2020) is the development of *curcumin* nano formulations. Numerous nano formulations have been developed to enhance *curcumin's* oral bioavailability and tackle its therapeutic problems in the treatment of diabetes, including self-nano phospholipid dispersions, nanoparticles, nano carriers, and nano micelles. In diabetic rats, these nano formulations show improved pharmacological effects, such as lowered blood glucose levels, increased insulin expression, and improved treatment results. Clinical studies have also demonstrated the ability of nano *curcumin* to improve lipid profiles, blood glucose, and glycosylated hemoglobin in diabetic patients, among other diabetes-related parameters. The delivery of *curcumin* using nanotechnology offers the potential for more focused and efficient diabetic treatment interventions (Shamsi-Goushki, 2020).

Resveratrol: Resveratrol is a phytoalexin with pharmacological activity, including anti-cancer, anti-cardiovascular disease, and life-span-increasing qualities. It exists in two isomeric forms, trans and cis (Figure 3) (Fan, 2005). For *resveratrol* to have the intended therapeutic benefits, dose escalation and frequent dosing are required due to its poor pharmacokinetic and biopharmaceutical qualities. These problems can be solved by a variety of tactics, including prodrugs, chemical changes, bio enhancers, and innovative pharmaceutical formulations. *Resveratrol* has, however, shown advantages over other methods when nano encapsulated in lipid nano carriers, nano emulsions, micelles, polymeric particles, solid dispersions, and nanocrystals (Yücel, 2018).

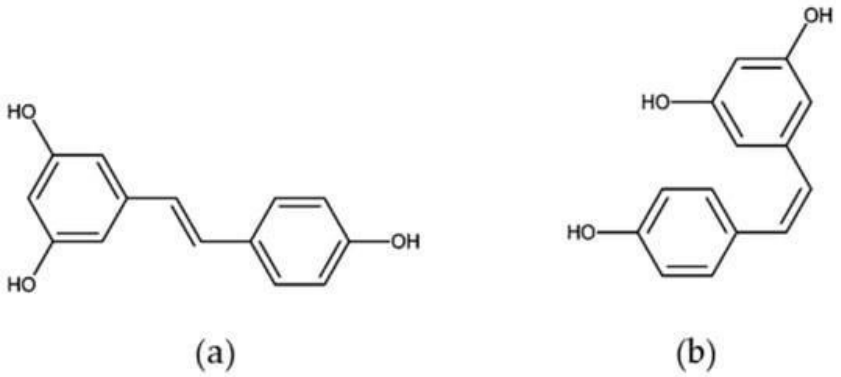

Figure 3. Configuration of trans-resveratrol (a) and cis-resveratrol (b) (Jarosova, 2020).

These nano formulations have higher levels of therapeutic efficacy, specific targeting, stability, bioavailability, and patient compliance. Layer-by-layer nano formulations, solid lipid nanoparticles, casein nanoparticles, nano liposomes, nano cochleates, and nano emulsions are a few examples that show promise in the treatment of type 2 diabetes and its related microvascular problems (Meng, 2021). Certain formulations exhibit encouraging results in terms of long- lasting benefits, increased oral bioavailability, and the capacity to reverse insulin resistance in rats with diabetes. The lack of a report on *resveratrol* nano formulation clinical trials on humans with diabetes is emphasized, nevertheless.

Naringenin: Citrus fruits naturally contain *naringenin*, a flavonoid with a range of pharmacological effects. (Cai J., 2023) Pharmacological approaches such as the application of P-gp inhibitors, metabolic inhibitors, and solubility enhancers have been utilized to enhance *naringenin's* pharmacokinetic and biopharmaceutical characteristics. However, a viable approach to overcoming pharmacological obstacles and boosting *naringenin's* therapeutic efficacy is formulation design based on nanotechnology. Various nano formulations have been developed to enhance the oral bioavailability, dissolution, and clinical relevance of *naringenin*. These include nano emulsification, self-nano emulsified delivery systems, soluthin-maltodextrin nano carriers, liposomal nano formulations, and chitosan core- shell nanoparticles. When compared to free *naringenin*, these nano formulations show improved drug release, absorption, and decreased toxicity, which suggests that they could lead to better therapeutic results. Although *naringenin* nano formulations for a variety of disorders have advanced, their precise role in managing diabetes remains restricted (Stabrauskiene, 2022).

2.6 Research on creating antidiabetic drugs *in vivo*

Many of the metabolic pathways that diabetes affects in human tissues are treatable with medication (Venter, 2008). In this regard, animal models are more appropriate for evaluating the anti-diabetic properties of medicinal plants. Here, comprehensive information on in-vivo tests for a few plants that may have anti-diabetic properties were included.

Vernonia amygdalina Del. (Asteraceae): Within the *Vernonia genus*, *Vernonia* is the most commonly utilized plant. The ethanolic extraction of *Azadirachta indica*, or *neem*, demonstrated its anti-diabetic properties in an animal. Acrid leaves and a specific extraction mixture cause an animal's plasma glucose to drop, which helps distinguish between chlorpropamides and non-diabetic controls. These findings corroborated a prior investigation using *Vernomia amygdalina* extraction, which revealed a minimal glycemic effect in diabetic animals (Adejuwon, 2005).

Hypoxis hemerocallidea Fisch. (Hypoxidaceae): Most commonly used in African therapy plants is *Hypoxis hemerocallidea*. Regarding the anecdotal claim that *hemerocallidea* has anti-diabetic qualities, there aren't many scientific studies. Aqueous extraction of streptozotocin (STZ) was used, and the impact on diabetic rats was seen. In diabetic rats induced by STZ, typical outcomes include elevated blood glucose levels (hyperglycemia), altered lipid metabolism, potential weight loss, and in severe cases, diabetic complications such as neuropathy and nephropathy. (Ojewole, 2006).

Gymnema sylvestre (Apocynaceae): The woody climber *Gymnema sylvestre (Asclepiadaceae)* is found in the tropical woods of central and southern India. A water- soluble *Gymnema sylvestre* leaf extract reduced blood glucose levels in diabetic rats by regenerating pancreatic islets and beta cells. An aqueous dissolved fraction of the alcohol extraction of *Gymnema sylvestre* leaves decreased the tissue's amount of glycogen in glucose-fed rats, but had no effect on normal rats. A 400 mg daily dose of *Gymnema sylvestre* water-soluble extract dramatically decreased insulin requirements in T2DM patients while simultaneously reducing HbA1c levels (Shanmugasundaram, 1990).

3. Results and Discussion

3.1 The bioactive compound's antioxidant action in diabetes

Free radicals can be efficiently targeted by compounds that have the ability to scavenge free radicals. Free radicals are linked to a number of disorders, such as diabetes, heart disease, cancer, and hepatic cirrhosis. Diabetes is a global health issue that has substantial consequences for morbidity, mortality, and the economy, especially in low- and middle-income countries where over 50% of cases go undiagnosed. Particularly in South Africa, the high prevalence of untreated diabetes patients has a major effect on the working-age population. The rising incidence of diabetes is intimately linked to oxidative stress, in which oxygen-free radicals exacerbate long-term difficulties by causing lipid peroxidation, protein glycation, and structural alterations in collagen and other membranes (Wu, 2014). Phyto constituents from medicinal plants, such as flavonoids and polyphenols, exhibit antioxidant properties, acting as free radical scavengers. For instance, mulberry fruit polysaccharides and polyphenolic compounds present in litchi pulp demonstrate potent antioxidant and anti-diabetic effects. The antioxidant capacity, tested using DPPH and H2O2 methods, supports the hypothesis that phyto constituents can effectively scavenge free radicals, mitigating the destructive impact of hydroxyl radicals associated with cancer, mutagenesis, and cytotoxicity. Additionally, hydrogen donation to DPPH radicals contributes to antioxidant properties, with readings taken in triplicate and represented as mean± SEM. The study provides valuable insights into the potential use of phyto constituents for managing oxidative stress-related complications, including diabetes (Devi, 2023).

3.2 Plant-based nanoparticles for the treatment of diabetes

Ginger nanomaterials: When high-fat diet-fed rats were given ginger-derived nanoparticles (GDNP), insulin resistance improved and diet-induced obesity was prevented. The study examined the profile of gene expression in the mice treated with GDNP in their liver, gut, and fat tissue. To investigate the relationship between the Foxa2 protein and phosphatic acid-lipid nanoparticles, surface plasmon resonance (SPR) was used. The study tackles the worldwide problem of obesity brought on by high-fat meals and emphasizes how GDNP can prevent serious chronic illnesses like type 2 diabetes by reestablishing the balance of gut epithelial Foxa2-mediated signaling (Kumar, 2022).

Curcumin nanomaterials: Diabetes is a complicated metabolic disease that needs lifetime care and lifestyle modifications. *Curcumin* has poor absorption and solubility; nevertheless, formulations based on nanotechnology can improve its anti-diabetic effects. With its enhanced pharmacological routes, nano *curcumin* exhibits promise as a medication for the pharmaco therapeutic treatment of diabetes (Yallapu, 2015).

Selenium nanomaterials: The main goal of treating diabetes is to block *alpha-amylase* in order to lower post-carbohydrate hyperglycemia. The chosen extract dramatically reduced fasting glucose levels in diabetic rats and had very modest impacts on triglyceride, cholesterol, and LDL lowering (Mollania, 2021).

3.3 Plants with anti-diabetic properties

Aloe vera: Aloe vera extract dramatically decreased blood glucose, triglycerides, LDL cholesterol, and total cholesterol in diabetic mice when given at a daily dose of 130 mg/kg. Furthermore, in NIH/3T3 cells, a lyophilized aqueous *aloe* extract (1 mg/mL) boosted GLUT-4 mRNA production. Research shows that in stz-induced diabetes, *aloe vera* extract improves pancreatic-cell activity, insulin production, and pancreatic islet mass restoration (Noor, 2017).

Black carrot: The phenolic chemicals found in *black carrots* have the ability to treat Type 2 diabetes. In an in vitro study, *vildagliptin* outperformed traditional inhibitors acarbose in terms of inhibitory activity against DPP-IV, although pure black *carrot* extract had greater efficacy against *glucosidase* and *amylase*. *Anthocyanin* compounds have shown promise as inhibitors in silico, particularly *cyanidin 3-xylosyl galactoside*, indicating that they may be useful in inhibiting enzymes linked to diabetes. Additionally, the encapsulation of anthocyanins in cyclodextrin was investigated. According to this study, *cyanidin 3-xylosyl galactoside* is a promising chemical that can inhibit enzymes involved in glucose metabolism. This highlights the potential benefits of anthocyanins found in *black carrots* for managing diabetes (Karkute, 2018).

3.4 Patents search for bioactive components used for treatment of diabetes

Many researches are being conducted in the world and in Turkey for the treatment of diabetes, and some of these treatments are being presented as ground breaking new discoveries. Notably, there are several plant-based drug discoveries that have been patented in Turkey, demonstrating the country's commitment to integrating traditional botanical knowledge with modern scientific research to develop effective and innovative diabetes therapies. The inventions patented in Turkey are listed below:

FERULA ELEAOCHYTRIS ROOT EXTRACT SOLUTION FOR USE IN THE TREATMENT OF ERECTILE DYSFUNCTION

(TÜRKİYE Patent No. 2020/04775 , 2020)

The *ferula eleaochytris* root extract solution is the subject of this invention. It was created specifically for the pharmaceutical industry and to treat erectile dysfunction caused by diabetes. Its features include: drying the plant's root after removing dirt and foreign objects from its outer surface; powdering the dried roots; extracting the powdered plant using a solvent that contains diethyl sweat; and extracting the pure extract that is left over after the extraction process. The steps in the process are to dissolve it in its own solvent, which should comprise at least 0.1 ml of ethanol and 0.9 ml of

distilled water diethyl ether, and then to obtain the oral solution of the root extract.

A HERBAL MEDICINE USED IN THE TREATMENT OF DIABETES

(TÜRKİYE Patent No. 2021/011385, 2021)

The invention relates to a herbal medication that contains *fenugreek, nettle, andcranberry* and is used to treat diabetes. The innovation is specifically related to technique of producing herbal medication and using it to treat type I and/or type II diabetes.

A HERBAL CREAM USED IN TREATMENT OF WOUNDS

(TÜRKİYE Patent No. 2021/011386 , 2021)

The invention relates to a herbal cream that contains *calendula, beeswax oil, sesame oil*,and the herb *Arnebia euchroma* for the purpose of treating wounds. The innovation is specifically related to a herbal cream and production process that are used to treat bad sores and wounds associated with diabetes type I and/or type II.

EXTRACT METHOD OF HIGH PURITY ANTHOCYANIDINS FOR DIABETES

(TÜRKİYE Patent No. 2022/012027 , 2022)

The invention relates to the extraction of high-purity anthocyanidins for diabetic patients. These anthocyanins are derived from the *barberry plant*, which has a high capacity for antioxidants and is extracted, separated, and evaporated using natural, healthful, and body-friendly processes that lower blood sugar levels.

VEGAN CONFECTIONS AND FOOD SUPPLEMENTS CONTAINING ANTIHYPERTENSIVE, ANTIDIABETIC, ANTI-ALZHEIMER ORANTIOXIDATIVE VEGETABLE PROTEIN HYDROLYSATES

(TÜRKİYE Patent No. 2023/005594 , 2023)

Using naturally occurring oilseed pulps like *hazelnut, black cumin, pumpkin,* and *sunflower*, as well as minor products like *plum, pomegranate, grape,* and *pepper seed pulp*, as well as the bran fractions and germ of grain raw materials (*sesame, oat, wheat,etc.*), the invention is based on the production of protein isolates. The proteins in these isolates are then broken down with the right proteolytic enzymes, the resulting degradation products (hydrolysates) are fractionated using the right ultrafiltration techniques, and the highest bioactive properties (antihypertensive, antidiabetic, antioxidative, or anti-Alzheimer activity) are chosen from the fractions and converted into a relatively stable powder form or it focuses on the preparation of raw materials, which includes turning them into liquid, concentrated forms, making vegan candy, andfood supplements containing these raw materials.

4. Conclusion

In conclusion, medicines derived from plants and developments in diabetes mark a ground breaking era in modern medicine. Innovations in these fields offer promising perspectives for effectively treating diseases and improving human health.

Nanotechnology plays an important role in the design and development of drug delivery systems. Nano-sized carrier systems allow drugs to reach targeted areas more effectively and keep the dosage under control. This allows the development of more precise and effective treatments for the management of chronic diseases such as diabetes.

Medicines derived from plants form the basis of traditional medicine as well as modern drug development. Bioactive components obtained from natural sources attract attention due to their antioxidant properties and positive effects on health. Especially in the fight against diabetes, herbal medicines play an important role in traditional medicine and offer new treatment options.

Diabetes continues to be an increasing public health problem worldwide. However, nano technology and medicines derived from plants hold promise for alleviating difficulties in diabetes management and developing more effective treatment methods. Nano-sized drug carriers can increase the effectiveness of treatment by directing important molecules such as insulin to the target. At the same time, herbal medicines can improve glycemic control and minimize side effects by interfering with the metabolic pathways of diabetes.

As a result, nanotechnology and drugs derived from plants hold promise for the development of more effective and personalized treatment options in the future for the management of diabetes and similar chronic diseases. Integration of these technologies can contribute to treating diseases more effectively and improving patients' quality of life.

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