EUROPEAN JOURNAL OF BIOMEDICAL AND PHARMACEUTICAL SCIENCES
http://www.ejbps.com

ISSN 2349-8870
Volume: 11
Issue: 8
80-88
Year: 2024

THE PHARMACOLOGICAL ASSESSMENT OF CARISSA CARANDAS (L.) IN DIABETICS

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Article Received on 11/06/2024 **Article Revised on 02/07/2024** **Article Accepted on 23/07/2024**

ABSTRACT
Carissa carandas (L.) is investigated for its potential therapeutic role in managing diabetes mellitus, a chronic metabolic disorder characterized by hyperglycemia. This review synthesizes current research findings on the pharmacological properties of *Carissa carandas* relevant to diabetes treatment. The plant exhibits significant antidiabetic effects through various mechanisms, including enhancement of insulin secretion, improvement of insulin sensitivity, inhibition of carbohydrate digestive enzymes (alpha-amylase and alpha-glucosidase), and modulation of hepatic gluconeogenesis. These mechanisms collectively contribute to reducing blood glucose levels and mitigating postprandial hyperglycemia. Experimental studies have demonstrated the efficacy of *Carissa carandas* extracts in lowering blood glucose levels in diabetic animal models, suggesting its potential as a natural alternative or adjunct to conventional antidiabetic therapies. Further clinical trials are warranted to validate these findings and establish the safety and efficacy of *Carissa carandas* in human subjects. Mechanistic studies should focus on elucidating the specific molecular pathways involved in its antidiabetic effects, while efforts to standardize extracts and formulations are essential for ensuring consistency in therapeutic outcomes. In conclusion, *Carissa carandas* holds promise as a novel therapeutic agent for diabetes management, though further research is needed to fully understand its clinical potential and integration into diabetes treatment protocols.

KEYWORDS: Carissa carandas, Diabetes mellitus, Antidiabetic, Glucose metabolism, Phytochemicals.

I. INTRODUCTION

Diabetes mellitus is a chronic metabolic disorder characterized by elevated levels of blood glucose (hyperglycemia) due to defects in insulin secretion, insulin action, or both.[1] The condition is broadly classified into two main types: Type 1 diabetes, which is primarily due to autoimmune destruction of pancreatic beta cells resulting in an absolute deficiency of insulin, and Type 2 diabetes, which is characterized by insulin resistance and a relative deficiency of insulin. Other specific types include gestational diabetes, which occurs during pregnancy, and other rare forms due to genetic mutations or other diseases affecting the pancreas.[2]

Prevalence and Impact

The prevalence of diabetes has been rising globally, making it a significant public health concern. According to the International Diabetes Federation (IDF), approximately 537 million adults (20-79 years) were living with diabetes in 2021, a number projected to increase to 643 million by 2030 and 783 million by 2045.[3] This rise in prevalence is largely driven by lifestyle factors such as poor diet, physical inactivity, and increasing obesity rates. Diabetes is associated with severe complications including cardiovascular diseases, neuropathy, nephropathy, and retinopathy, which contribute to increased morbidity and mortality among affected individuals. The economic burden of diabetes is substantial, with significant costs related to healthcare, loss of productivity, and long-term care. In 2021, global health expenditure on diabetes reached USD 966 billion, highlighting the urgent need for effective management and prevention strategies.[3-4]

B. Importance of Natural Remedies in Diabetes Management

Carissa carandas (L.), commonly known as Karonda or Christ's Thorn, is a species of flowering shrub in the family Apocynaceae. It is a hardy, evergreen plant that typically grows to a height of 2 to 4 meters. The shrub

has spiny branches and is characterized by its dark green, glossy leaves that are ovate to elliptic in shape. The plant produces small, fragrant white flowers that bloom in clusters. The fruit of *Carissa carandas* is a berry, which changes color from green to pink, and eventually to dark purple or black when fully ripe. The berries are rich in nutrients and have a tart taste, making them suitable for various culinary uses.[5-6]

Traditional Uses

Carissa carandas has been traditionally used in various cultures for its medicinal properties. In Ayurvedic medicine, the fruit, roots, and leaves of the plant are utilized for their health benefits. The fruit is known for its digestive properties and is used to treat gastrointestinal issues such as indigestion, constipation, and anorexia. It is also employed in the treatment of skin infections, wounds, and ulcers due to its antiseptic properties. The roots and leaves are used in the preparation of herbal remedies for fever, earache, and scabies. Additionally, the plant is believed to have cardiotonic, anti-inflammatory, and antimicrobial properties. In some regions, the fruit is also consumed as a remedy for anemia and to boost overall health due to its rich vitamin C content.[7-9]

II. Phytochemical Profile of (*Carissa carandas)*Major Phytochemical Constituents

Alkaloids

Alkaloids are a diverse group of naturally occurring organic compounds that mostly contain basic nitrogen atoms. In *Carissa carandas*, alkaloids have been identified as significant constituents. These compounds exhibit a wide range of biological activities, including antimicrobial, analgesic, and anti-inflammatory properties. Alkaloids such as carissine and carindone have been isolated from the roots and leaves of the plant, contributing to its medicinal properties.[10]

Flavonoids

Flavonoids are a class of polyphenolic compounds known for their antioxidant, anti-inflammatory, and anticancer activities. *Carissa carandas* is rich in flavonoids, particularly in its fruits and leaves. These compounds help in scavenging free radicals, thereby protecting cells from oxidative stress and reducing the risk of chronic diseases. Quercetin, kaempferol, and myricetin are among the notable flavonoids found in *Carissa carandas*, contributing to its therapeutic potential in managing conditions like diabetes and cardiovascular diseases.[11]

Glycosides

Glycosides are compounds in which a sugar is bound to a non-carbohydrate moiety, usually a small organic molecule. They are known for their therapeutic properties, including cardioprotective, anti-inflammatory, and antimicrobial effects. In *Carissa carandas*, various glycosides such as cardiac glycosides have been identified, which play a crucial role in its use as a cardiotonic. These compounds help in strengthening the heart muscles and improving its efficiency in pumping blood, which is particularly beneficial in treating heart-related ailments.[11]

Saponins

Saponins are glycosides with foaming characteristics. They have a wide range of pharmacological properties, including antioxidant, anti-inflammatory, and immune-modulatory effects. The presence of saponins in *Carissa carandas* contributes to its traditional use in treating various ailments. These compounds enhance the bioavailability of nutrients and other phytochemicals, support immune function, and possess potential anti-cancer properties. The saponins found in *Carissa carandas* are also believed to contribute to its efficacy in managing diabetes by influencing glucose metabolism.[12-13]

B. Methods of Phytochemical Analysis

Chromatography Techniques

Chromatography techniques are essential tools for the separation, identification, and quantification of phytochemicals in plant extracts. In the analysis of *Carissa carandas*, several chromatographic methods are commonly used:[14]

- **Thin Layer Chromatography (TLC):** TLC is a simple, rapid, and cost-effective technique used to screen for the presence of various phytochemicals in *Carissa carandas*. Extracts are applied as small spots on a TLC plate coated with a thin layer of silica gel. The plate is then developed in a solvent system, and different phytochemicals migrate at different rates, forming distinct spots that can be visualized using UV light or specific reagents.[16]
- **High-Performance Liquid Chromatography (HPLC):** HPLC is a more advanced technique that provides high resolution and sensitivity for the analysis of phytochemicals. It is commonly used to quantify flavonoids, alkaloids, and glycosides in *Carissa carandas*. The plant extract is injected into a column packed with a stationary phase, and the compounds are eluted with a mobile phase under high pressure. The separated compounds are detected by UV or mass spectrometry, allowing for precise identification and quantification.[17]
- **Gas Chromatography-Mass Spectrometry (GC-MS):** GC-MS is used for the analysis of volatile and semi-volatile compounds, such as essential oils and some alkaloids in *Carissa carandas*. The extract is vaporized and carried by an inert gas through a column, where the compounds are separated. They are then ionized and detected by mass spectrometry, providing detailed information about the molecular structure and concentration of the compounds.[18]

Spectroscopy Techniques

Spectroscopy techniques are vital for the structural elucidation and quantification of phytochemicals. The

following methods are commonly used in the analysis of *Carissa carandas*:

- **UV-Visible Spectroscopy:** This technique measures the absorption of UV and visible light by phytochemicals in the extract. It is often used to quantify total phenolic and flavonoid content. The absorbance is measured at specific wavelengths corresponding to the compounds of interest, providing a quick and accurate estimation of their concentrations.[19]
- **Fourier Transform Infrared Spectroscopy (FTIR):** FTIR is used to identify functional groups and characterize the molecular structure of phytochemicals. The extract is subjected to infrared radiation, and the resulting spectrum provides information about the different functional groups present based on their characteristic absorption bands.[20]
- **Nuclear Magnetic Resonance (NMR) Spectroscopy:** NMR spectroscopy is a powerful tool for determining the detailed structure of phytochemicals. It provides information about the number and types of atoms in a molecule and their spatial arrangement. This technique is especially useful for elucidating the structures of complex organic compounds like alkaloids and glycosides in *Carissa carandas*.[21]
- **Mass Spectrometry (MS):** MS is used to determine the molecular weight and structure of phytochemicals. It involves ionizing chemical compounds to generate charged molecules or molecule fragments and measuring their mass-to-charge ratios. Coupled with chromatographic techniques, MS provides detailed structural information and aids in the identification of phytochemicals.[22]

III. Pharmacological Activities of *Carissa carandas*

Mechanisms of Action

The antidiabetic properties of *Carissa carandas* are attributed to several bioactive compounds present in the plant, which act through multiple mechanisms to regulate blood glucose levels:

- **Inhibition of α-glucosidase and α-amylase:** The fruit and leaves of *Carissa carandas* contain compounds that inhibit the activity of α-glucosidase and α-amylase, enzymes responsible for carbohydrate digestion. By inhibiting these enzymes, the plant reduces the breakdown of complex carbohydrates into glucose, thereby lowering postprandial blood glucose levels.[23-24]
- **Enhancement of Insulin Secretion:** *Carissa carandas* extracts have been shown to stimulate insulin secretion from pancreatic β-cells. This action helps in maintaining normal blood glucose levels, particularly in individuals with insulin resistance or type 2 diabetes. The exact phytochemicals responsible for this effect include flavonoids and alkaloids.[25-26]
- **Antioxidant Activity:** Oxidative stress plays a crucial role in the development and progression of diabetes and its complications. The antioxidant properties of *Carissa carandas* are due to the presence of flavonoids, phenolics, and vitamins. These antioxidants scavenge free radicals, reducing oxidative damage to pancreatic β-cells and improving their function.[27-28]
- **Anti-inflammatory Effects:** Chronic inflammation is associated with insulin resistance and type 2 diabetes. *Carissa carandas* exhibits anti-inflammatory effects by inhibiting pro-inflammatory cytokines and enzymes such as cyclooxygenase (COX). This reduces inflammation in tissues and enhances insulin sensitivity.[29-30]

Comparative Studies with Standard Antidiabetic Drugs

Several studies have compared the efficacy of *Carissa carandas* with standard antidiabetic drugs to assess its potential as an alternative or adjunct therapy:

- **Comparison with Metformin:** In animal models, *Carissa carandas* extracts have been shown to significantly reduce blood glucose levels, comparable to the effects of metformin, a widely used antidiabetic drug. These studies highlight the potential of the plant in managing hyperglycemia without the side effects associated with synthetic drugs.[31-32]
- **Synergistic Effects with Insulin:** Some studies have explored the combined use of *Carissa carandas* extracts with insulin. The results indicate a synergistic effect, where the combination improves glycemic control more effectively than insulin alone. This suggests that the plant could enhance the efficacy of insulin therapy in diabetic patients.[33-34]
- **Comparison with Sulfonylureas:** Sulfonylureas, such as glibenclamide, are another class of antidiabetic drugs. Research indicates that *Carissa carandas* extracts have similar or superior glucose-lowering effects compared to sulfonylureas. Additionally, the plant extracts have the advantage of fewer hypoglycemic episodes, which is a common side effect of sulfonylureas.[35-36]
- **Impact on Lipid Profile:** Beyond glucose regulation, *Carissa carandas* has been studied for its effects on lipid profiles. It has been found to reduce total cholesterol, low-density lipoprotein (LDL) cholesterol, and triglycerides, while increasing high-density lipoprotein (HDL) cholesterol. These effects are comparable to those of statins, indicating potential benefits for cardiovascular health in diabetic patients.[37-38]

B. Antioxidant Activity

Free Radical Scavenging

Carissa carandas exhibits significant antioxidant activity, primarily through its ability to scavenge free radicals. Free radicals are unstable molecules that can

cause oxidative stress, leading to cellular damage and contributing to various diseases, including diabetes.

- **Mechanism:** The antioxidant compounds in *Carissa carandas*, such as flavonoids, phenolics, and vitamins, neutralize free radicals by donating electrons or hydrogen atoms. This action stabilizes the free radicals and prevents them from causing cellular damage.[39]
- **Evidence:** Studies have demonstrated that extracts of *Carissa carandas* show strong free radical scavenging activity in vitro. For instance, the DPPH (2,2-diphenyl-1-picrylhydrazyl) assay is commonly used to measure this activity. The extracts reduce DPPH radicals to a non-radical form, indicating their potent scavenging ability. Another assay, the ABTS (2,2'-azinobis(3-ethylbenzothiazoline-6-sulfonic acid)) radical scavenging assay, has also shown positive results for *Carissa carandas* extracts, further confirming their antioxidant potential.[40]

Redox Homeostasis

Redox homeostasis refers to the balance between the production of reactive oxygen species (ROS) and the antioxidant defenses of the body. Maintaining redox homeostasis is crucial for preventing oxidative stress-related damage.

- **Mechanism:** *Carissa carandas* contributes to redox homeostasis by enhancing the body's endogenous antioxidant defenses. The phytochemicals present in the plant upregulate the expression of antioxidant enzymes such as superoxide dismutase (SOD), catalase, and glutathione peroxidase. These enzymes play a vital role in neutralizing ROS and maintaining cellular redox balance.[41]
- **Evidence:** Research indicates that *Carissa carandas* extracts can increase the activity of these antioxidant enzymes in animal models. For example, in diabetic rats, treatment with *Carissa carandas* extracts led to a significant increase in the levels of SOD, catalase, and glutathione peroxidase compared to untreated controls. This suggests that the plant not only scavenges free radicals directly but also boosts the body's own antioxidant defense system.[42]

Other Relevant Pharmacological Activities

Anti-inflammatory

Carissa carandas has been traditionally used for its anti-inflammatory properties, which have been supported by modern pharmacological studies. Inflammation is a key component in the pathogenesis of various chronic diseases, including diabetes.

- **Mechanism:** The anti-inflammatory activity of *Carissa carandas* is primarily attributed to its phytochemicals, such as flavonoids, saponins, and tannins, which inhibit the production of pro-inflammatory mediators. These compounds can reduce the activity of cyclooxygenase (COX) enzymes, which are responsible for the synthesis of prostaglandins, key mediators of inflammation. Additionally, they inhibit the release of cytokines like TNF-α, IL-1β, and IL-6, which play a crucial role in the inflammatory response.[43]
- **Evidence:** In animal models, *Carissa carandas* extracts have been shown to significantly reduce inflammation. For example, in a study using carrageenan-induced paw edema in rats, the administration of *Carissa carandas* extract resulted in a significant reduction in paw swelling, comparable to the effect of standard anti-inflammatory drugs like indomethacin. This suggests that the plant has potent anti-inflammatory effects that can be beneficial in conditions associated with chronic inflammation.[44]

Antihyperlipidemic

Hyperlipidemia, characterized by elevated levels of lipids in the blood, is a major risk factor for cardiovascular diseases, which are common complications of diabetes. *Carissa carandas* has been found to have antihyperlipidemic effects, helping to manage lipid levels and reduce cardiovascular risk.

- **Mechanism:** The antihyperlipidemic activity of *Carissa carandas* is due to its ability to modulate lipid metabolism. The phytochemicals in the plant, such as flavonoids and saponins, can enhance the activity of lipoprotein lipase, an enzyme involved in the breakdown of lipids. They also inhibit the synthesis of cholesterol in the liver and promote the excretion of bile acids, leading to reduced cholesterol levels.[45-46]
- **Evidence:** Studies have shown that *Carissa carandas* extracts can significantly lower total cholesterol, LDL cholesterol, and triglycerides, while increasing HDL cholesterol levels. In one study, diabetic rats treated with *Carissa carandas* extract showed a significant reduction in serum lipid levels compared to untreated diabetic controls. These effects were comparable to those of standard lipid-lowering drugs like atorvastatin, indicating the potential of *Carissa carandas* as an antihyperlipidemic agent.[47-48]

IV. Preclinical Studies

A. Animal Models Used

Rodent Models (Wistar Rats, etc.)

Rodent models, particularly Wistar rats, are commonly used in pharmacological research due to their genetic, biological, and behavioral similarities to humans. They provide a controlled environment to study the effects of various substances, including plant extracts, on metabolic and physiological processes relevant to human diseases such as diabetes.

- **Wistar Rats:** Wistar rats are a standard breed used in laboratory research. They are preferred for their calm nature, ease of handling, and well-documented physiology. These rats have been extensively used to study the pathophysiology of diabetes and the potential therapeutic effects of antidiabetic agents.[49]

- **Other Rodent Models:** Besides Wistar rats, other rodent models like Sprague-Dawley rats and genetically modified mice (e.g., ob/ob mice, db/db mice) are also employed in diabetes research. Each model has unique characteristics that make them suitable for specific types of studies. For instance, genetically modified mice can be used to study the genetic basis of diabetes.[50]

Induction of Diabetes in Animal Models

To study the antidiabetic properties of *Carissa carandas*, diabetes is induced in rodent models using various methods that mimic the human diabetic condition. These models help in evaluating the efficacy and safety of potential antidiabetic agents.

Chemical Induction: One of the most common methods for inducing diabetes in rodents is through the administration of chemicals like streptozotocin (STZ) and alloxan. These chemicals selectively destroy insulin-producing β-cells in the pancreas, leading to hyperglycemia. STZ is particularly favored for its reliability and ability to induce a diabetic state that closely resembles type 1 diabetes in humans.[51]

- **Procedure:** Typically, rats are fasted overnight and then injected with a single dose of STZ (usually 45-55 mg/kg body weight) dissolved in citrate buffer. The diabetic state is confirmed after 48-72 hours by measuring fasting blood glucose levels. Rats with blood glucose levels above 250 mg/dl are considered diabetic and are included in the study.[52]

Diet-Induced Models: Type 2 diabetes can be induced by feeding rodents a high-fat diet (HFD) or a diet high in sucrose/fructose, often combined with low-dose STZ. This method replicates the metabolic syndrome seen in type 2 diabetes, including insulin resistance and obesity.

- **Procedure:** Rodents are fed an HFD (typically 60% fat by calories) for several weeks. This diet leads to obesity and insulin resistance. To enhance the diabetic state, a low dose of STZ (25-35 mg/kg) may be administered after several weeks on the HFD. The combination of diet and STZ treatment results in a model that mimics human type 2 diabetes.[53]

VI. Mechanisms of Antidiabetic Action

A. Insulin Secretion and Sensitivity

Carissa carandas has been investigated for its potential to modulate insulin secretion and improve insulin sensitivity, crucial factors in managing diabetes mellitus.

- **Insulin Secretion Enhancement**
  - **Mechanism:** *Carissa carandas* extracts contain bioactive compounds such as polyphenols, flavonoids, and alkaloids that may stimulate insulin secretion from pancreatic β-cells. These compounds interact with cellular receptors and signaling pathways involved in insulin release.[54]
  - **Evidence:** Studies have shown that *Carissa carandas* extracts can enhance insulin secretion in animal models of diabetes. This effect helps in maintaining blood glucose homeostasis by promoting the uptake of glucose into cells, thereby reducing hyperglycemia.[54]

- **Improvement of Insulin Sensitivity**
  - **Mechanism:** Insulin sensitivity refers to the responsiveness of target tissues (e.g., liver, muscle, adipose tissue) to insulin. *Carissa carandas* may improve insulin sensitivity by influencing cellular glucose uptake mechanisms and by enhancing insulin receptor signaling.[55]
  - **Evidence:** Research indicates that phytochemicals in *Carissa carandas* can activate AMP-activated protein kinase (AMPK) pathways, which play a key role in glucose metabolism and insulin sensitivity regulation. This activation enhances glucose uptake and utilization in peripheral tissues, thereby lowering blood glucose levels.[56]

B. Glucose Uptake and Utilization

Carissa carandas exhibits potential antidiabetic effects by enhancing glucose uptake and utilization in cells, thereby reducing blood glucose levels.

- **Enhanced Glucose Uptake**
  - **Mechanism:** Bioactive compounds in *Carissa carandas*, such as flavonoids and polyphenols, facilitate glucose uptake into cells by stimulating glucose transporter proteins (GLUTs). These compounds can activate pathways involved in GLUT translocation to the cell membrane, promoting glucose entry into cells.[57]
  - **Evidence:** Studies have demonstrated that *Carissa carandas* extracts increase glucose uptake in skeletal muscle and adipose tissue in diabetic animal models. This effect helps in lowering blood glucose levels by reducing the amount of glucose circulating in the bloodstream.[57]

- **Improved Glucose Utilization**
  - **Mechanism:** In addition to promoting glucose uptake, *Carissa carandas* may enhance glucose utilization within cells by optimizing metabolic pathways involved in glycolysis, glycogenesis, and mitochondrial function. This ensures efficient utilization of glucose for energy production and metabolic processes.[58]
  - **Evidence:** Research has shown that phytochemicals present in *Carissa carandas* extracts can activate enzymes involved in glucose metabolism, such as hexokinase and phosphofructokinase. These enzymes play a critical role in glycolysis, the initial step of glucose metabolism, leading to increased utilization of glucose for energy production.[59]

C. Inhibition of Carbohydrate Digestive Enzymes

Carissa carandas has demonstrated potential in inhibiting carbohydrate digestive enzymes, contributing to its role in managing postprandial blood glucose levels.

- **Alpha-Amylase Inhibition**
  - **Mechanism:** *Carissa carandas* extracts contain polyphenolic compounds that inhibit alpha-amylase, the enzyme responsible for breaking down starch into glucose in the digestive system. By inhibiting alpha-amylase, *Carissa carandas* reduces the rate of starch digestion and glucose release into the bloodstream after meals.[61]

- **Alpha-Glucosidase Inhibition**
  - **Mechanism:** *Carissa carandas* may also inhibit alpha-glucosidase enzymes, which hydrolyze complex carbohydrates into absorbable monosaccharides (glucose and other sugars). Inhibiting alpha-glucosidase delays carbohydrate digestion and absorption, thereby moderating postprandial glucose spikes.[62]
  - **Evidence:** Research has indicated that *Carissa carandas* extracts can effectively inhibit alpha-glucosidase activity, highlighting its potential therapeutic use in managing diabetes mellitus.[63]

D. Modulation of Hepatic Gluconeogenesis

Carissa carandas has been investigated for its potential to modulate hepatic gluconeogenesis, a critical pathway involved in regulating blood glucose levels.

Mechanism

- Gluconeogenesis Regulation: *Carissa carandas* extracts contain bioactive compounds that may influence key enzymes and signaling pathways involved in gluconeogenesis in the liver. Gluconeogenesis is the process by which the liver produces glucose from non-carbohydrate precursors (such as amino acids and glycerol), contributing to increased blood glucose levels in diabetes.[64]
- Evidence: Studies suggest that phytochemicals present in *Carissa carandas* may inhibit enzymes involved in gluconeogenesis, such as glucose-6-phosphatase and phosphoenolpyruvate carboxykinase. By inhibiting these enzymes, *Carissa carandas* can potentially reduce hepatic glucose production, thereby helping to lower blood glucose levels in diabetic conditions.[65]

IX. CONCLUSION

Carissa carandas (L.) has emerged as a promising candidate for managing diabetes mellitus, supported by compelling evidence from various studies. The plant's extracts have demonstrated significant antidiabetic properties through multiple mechanisms. Firstly, Carissa carandas enhances insulin secretion from pancreatic beta cells, facilitating glucose uptake by tissues and thereby lowering blood glucose levels effectively. Moreover, it improves insulin sensitivity, crucial for maintaining glucose homeostasis in diabetic conditions. These effects are complemented by the plant's ability to inhibit carbohydrate digestive enzymes like alpha-amylase and alpha-glucosidase, which reduces the postprandial rise in blood glucose levels. Additionally, Carissa carandas shows promise in modulating hepatic gluconeogenesis, the process by which the liver produces glucose from non-carbohydrate sources, further contributing to its antidiabetic efficacy.

Future research should focus on validating these findings through rigorous clinical trials involving larger, diverse patient populations. Such studies would provide essential insights into the efficacy and safety profile of Carissa carandas in long-term diabetes management. Mechanistic investigations are also warranted to elucidate the specific pathways through which Carissa carandas exerts its antidiabetic effects, potentially uncovering novel therapeutic targets. Standardization of extracts and formulations is critical to ensure consistency and reproducibility of therapeutic outcomes across different studies. Moreover, comparative studies with conventional antidiabetic drugs would elucidate the comparative efficacy and potential synergistic effects of Carissa carandas in diabetes treatment regimens. Addressing these aspects will be pivotal in advancing Carissa carandas as a valuable therapeutic agent for diabetes mellitus.

ACKNOWLEDGEMENT

I am appreciative to the college administration for offering the top labs, which I needed to do my research.

Conflict of Interest

The authors declare no conflict of interest.

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