Al-Nahrain Journal of Science
ANJS, Vol.28(2), June, 2025, pp. 62-72

The Effectiveness of Moringa Plant in Reducing Blood Sugar

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Article's Information

Received: 10.10.2024
Accepted: 23.01.2025
Published: 15.06.2025

Keywords:
Blood Sugar
Moringa Plant
Insulin Sensitivity
Glucose
Diabetes

Abstract

The purpose of this study was to assess the biological mechanisms underlying the effects of Moringa on blood sugar levels. Because of its many health benefits, moringa is crucial for effectively treating diabetes. The information was gathered by doing a comprehensive analysis of earlier research on the effects of moringa on insulin and blood sugar levels. An analysis of its impact on blood sugar levels was conducted using data from clinical studies. According to the findings, moringa lowers blood sugar, improves insulin sensitivity, enhances insulin levels, and lessens the liver's synthesis of glucose. The significance of endorsing moringa as a secure natural remedy for diabetics is underscored by our findings, which show it has the potential to be a successful supplemental medication to enhance blood sugar regulation.

http://doi.org/10.22401/ANJS.28.2.06
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1. Introduction

A class of metabolic illnesses collectively referred to as diabetes is a chronic illness marked by elevated blood sugar levels as a result of either insufficient insulin production by the body or ineffective insulin receptor response by body cells [1]. Because insulin is a hormone that is essential for controlling blood glucose levels, or sugars, any interference with this system can have major negative effects on one's health [2]. Typically, there are two primary classifications for this illness: Type 1 diabetes, which usually manifests in infancy or adolescence and necessitates lifelong insulin therapy, is caused by insufficient insulin production by the pancreas. The most prevalent kind of diabetes, type 2, is characterized by insufficient insulin production or a body that is resistant to the effects of insulin. This type is closely linked to obesity and lifestyle choices, and it can develop slowly and typically starts in adults [3]. In some Asian and African countries, the leaves and fruit pods of the Moringa tree are common cooking ingredients. Because the sharp taste of the leaves is reminiscent of horseradish, Moringa oleifera, as the tree is scientifically known, is also called the horseradish tree. Here, Moringa leaves are processed into powder and sold as a dietary supplement - supposedly with health-promoting effects. Moringa is said to help with numerous health problems: from diabetes, high blood pressure, and high cholesterol to allergies, rheumatic pain and cancer. Available evidence has been explored to substantiate the information presented above. The effects of diabetes on general health are profound. Blood sugar levels that are out of control can cause long-term problems that include: a higher risk of heart disease and stroke; diabetic neuropathy, nerve damage that can impair sensation or movement in the extremities; kidney failure brought on by high blood sugar levels that affect the kidneys; retinopathy, an eye condition that can cause vision loss; and wound problems where the delayed healing can increase the risk of infection [4, 5]. Because millions of people worldwide suffer from diabetes, it has become one of the most important health issues facing society, necessitating the need for safe and effective natural treatments. Effective treatment plans that assist patients in properly managing their diabetes has become more and more necessary as the number of diabetes cases, particularly type 2 diabetes, continues to rise [6]. There is an increasing trend towards looking for safe and natural remedies that help to improve blood sugar management and lessen the adverse effects that may arise from pharmaceuticals, even if standard medications like

insulin and sugar-lowering agents are an essential part of treatment [7].

Many people find natural cures appealing as they search for less invasive treatments with minimal side effects. These therapies range from herbal and medicinal plants to dietary and exercise modifications. These therapies are thought to improve the patient's general health and wellbeing in addition to helping to control blood sugar levels [8]. Moringa, scientifically known as Moringa oleifera, is considered one of the most nutritious plants on the planet. It is classified under the Moringaceae family. For moringa, there are a great number of names which include 'elephant tree' and 'miracle tree' owing to the various medicinal purposes and rich nutritional value of the plant [9]. Moringa leaves are an excellent dietary defined since they abound in vitamins, minerals and antioxidants. Furthermore they are rich in calcium, iron, protein and immunity boosting leaves promoting their general health. The moringa plant such as its leaves, seeds, and bark has found purpose in several traditional cultures for the treatment of different diseases [10]. New evidence supports the view that moringa can be used in combination with other treatment therapies to help improve diabetes care [11]. Moringa contains active substances such as phenolic acids and alkaloids, which are known to reduce inflammation and enhance insulin sensitivity, as such, blood sugar levels are affected favorably. Hence, incorporating moringa in the daily menu of the diabetic individual will help in enhancing the blood sugar levels in a natural healthy way without equipment jeopardizing one's health [12].

Moringa oleifera is recognized as one of the most beneficial trees globally, as nearly every part of the tree can be utilized for food, medicinal, and industrial purposes. It is extensively cultivated due to its remarkable adaptability to various climatic conditions and arid soils (Tiana, 2008; Rodríguez-Pérez et al., 2015). In this context, we aimed to investigate the antidiabetic properties of this plant, which is traditionally used in medicine to manage diabetes. The objective of this study is to examine the hypoglycemic and antidiabetic effects of aqueous extracts from Moringa oleifera leaves in vivo. Specifically, we focused on:

- Performing a maceration extraction on Moringa oleifera leaves to obtain a crude extract.
- Inducing type 1 diabetes in adult Wistar rats using Streptozotocin.
- Evaluating the antidiabetic activity of the crude extract in both healthy and diabetic rats.
- Assessing treatment effects by measuring changes in body weight, blood glucose levels, and triglycerides.
- Analyzing treatment effects through histological sections of specific organs, such as the liver and pancreas.

1.1. Insulin-dependent diabetes (IDD – type 1)

Type 1 diabetes is caused by autoimmune destruction of cells in the pancreas specialized in the production of insulin: the beta cells of the islets of Langerhans (Figure 1), It appears when only 10 to 20% of B cells remain functional. This type manifests itself at any age, but it is more common in children and young adults; they present about 10% of all people with diabetes (4).Risk factors for type 1 diabetes are still being studied. However, having a family member with type 1 diabetes slightly increases the risk of developing the disease. Environmental factors and exposure to certain viral infections have also been linked to the risk of developing type 1 diabetes.

1.2. Non-insulin-dependent diabetes (NIDDM–type 2)

Type 2 diabetes usually occurs because of two problems: resistance to insulin from peripheral tissues (insulin resistance: a situation where cells become less sensitive to this hormone) and a progressive loss of insulin secretion by the ß cells. According to the IDF Type 2 diabetes is the most common type, accounting for approximately 90% of all cases of diabetes; is most often diagnosed in older people, but it is seen more and more in children, adolescents and young adults due to increasing rates of obesity, physical inactivity and poor diet. These changes linked to rapid development and urbanization have led to a strong increase in the number of people with type 2 diabetes [6].

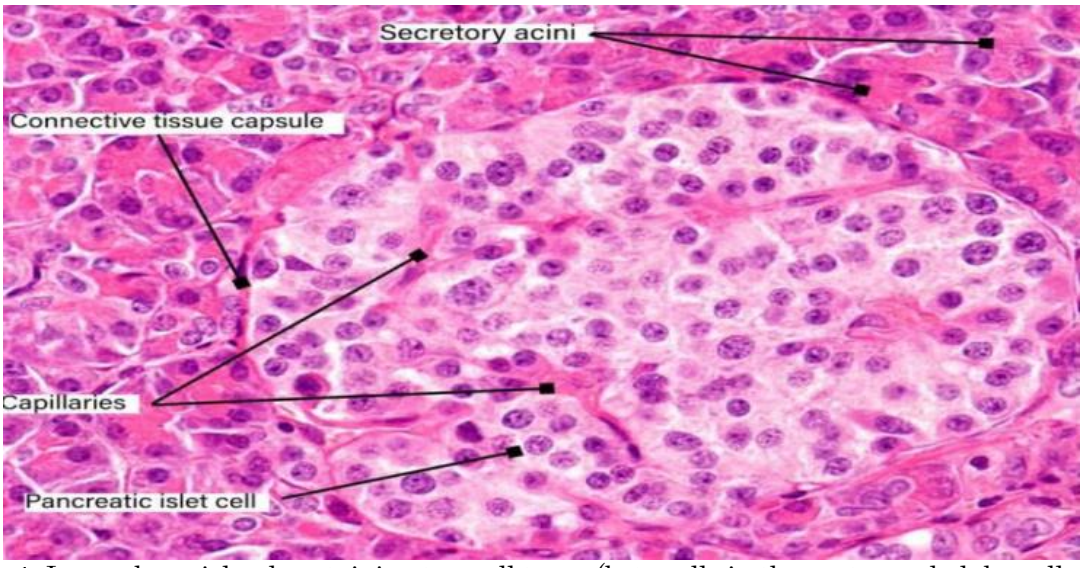

Figure 1: Langerhans island containing two cell types (beta cells in the center and alpha cells at the periphery)

1.3. Insulin hormone

Insulin is a polypeptide hormone composed of 51 amino acids, arranged in 2 chains (Kene mark .2008). The A and B chains of 21 and 30 amino acid residues respectively. Disulfide bonds of cysteine residues connect the 2 chains (Figure 2).

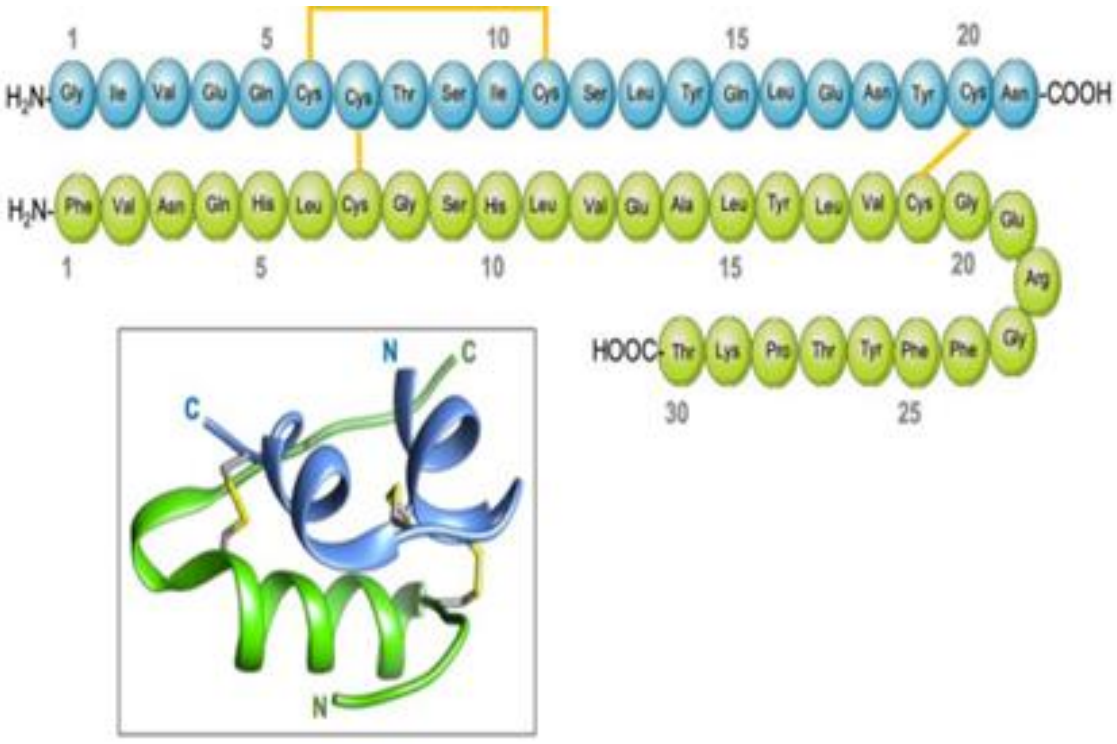

Figure 2: The primary and tertiary structure of insulin

Insulin-producing B cells are located in small groups of cells endocrine pancreatic cells known as islets of Langerhans. Each island contains up to about 2000 cells, with the largest islets having a diameter not exceeding nearly 0.2 mm. In addition to insulin-producing cells, the islets of Langerhans contain other types of endocrine cells secreting hormones such as glucagon, somatostatin and pancreatic polypeptide. B cells synthesize the polypeptide (insulin) in the form of preprohormone which is converted in the rough endoplasmic reticulum (RER) to proinsulin. Then, the formation of insulin in the Golgi apparatus. Cells of muscle tissue, vascular endothelium, heart and liver carry out the insulin-dependent cascade. The response generated by the effects of insulin in these cells is tissue specific. In adipose tissue, skeletal muscle and heart, the result is glucose metabolism via glucose absorption into cells. The first symptoms of diabetes (Table 1), particularly type 2 diabetes, can be subtle or seemingly harmless. You could have diabetes for months or even years and show no symptoms of diabetes.

Table 1: Symptoms of type 1 and type 2 diabetes

Diabetes Symptoms	Type 1 Diabetes	Type 2 Diabetes
Excessive thirst and dry mouth	Excessive thirst and dry mouth	Excessive thirst and dry mouth
Frequent urination	Abundant urination	Frequent and abundant urination
Lack of energy, fatigue	Lack of energy, fatigue	Extreme fatigue
Constant hunger	Constant hunger	Tingling or numbness in hands and feet
Sudden weight loss	Sudden weight loss	Recurrent skin fungal infections
Nocturnal incontinence	Nocturnal incontinence	Slow wound healing
Vision problems	Vision problems	Vision problems

2. Chemical Properties of Moringa Plant

2.1. Active compounds

Moringa oleifera Lam. Is a species native to the regions of Agra and Oudh, in the North-East of India, south of the Himalayan mountain range, it is cultivated today in all tropical and subtropical regions of the world. Its introduction into East Africa took place at the beginning of the 20th century through trade and maritime exchanges during this period Moringa oleiferais (Figure 2) is a small, fast-growing deciduous tree with evergreen which generally grows up to 10 or 12 m in height. He has a crown open and spreading with drooping and fragile branches, feathery foliage of tripinnate leaves and a thick, corky, whitish bark.

Figure 2: Moringa oleiferais tree.

The fruits are pendulous (figure 3), linear, three-sided pods with nine longitudinal ridges, generally 20 to 50 cm long, and 2.0 to 2.5 cm wide. The pods, each containing usually up to 26 dark green colored seeds as they develop take about 3 months to mature after flowering. A tree can produce 15,000 to 5,000 seeds per year. A seed weighs on average 0.3 g and the hull represents 25% seed weight.

Figure 3: Main parts of M. oleifera; A: The fruits , B: The leaves, C: the flowers, D: the trunk

Moringa oleifera is a highly therapeutic and nutritional plant with plenty of active substances. In this section, we highlight and discuss the main chemical compounds of Moringa (table 2):

1. Vitamins: Moringa leaves are rich in many vitamins but the two most crucial ones are Vitamin A and C. Vitamin A is essential for immunity and proper functioning of eyes, on the other hand, while vitamin C is a very potent antioxidant that boosts the immune system and helps the body to absorb iron. (Vitamin E) this vitamin helps in keeping one's skin healthy by protecting cells from damage caused by free radicals within the skin. (Vitamin B-complex) This category of vitamins plays a key role in generating energy and additionally other vitamins that promote and support metabolic activities [13].
2. Minerals: Moringa is rich in a necessary element for blood cell production (transport of oxygen) and preventing iron deficiency anaemia – iron. (Calcium) is required for healthy bones and teeth. - (mag-nesium) associated with several processes of chemical reactions in the system. (Potassium) assists in maintenance of the fluid balance and control of blood pressure [14].
3. Phenolic compounds: Moringa plant is enriched with a range of phenolic compounds which are potent antioxidants. For instance, (Chlorogenic acid) is one of the important compounds that is believed to lower blood sugar levels and appears to be anti-inflammatory. (Caffeic acid) is another compound that may be beneficial for overall health due to its free radical scavenging activity. (Other phenolic substances) that contain flavonoids for heart functioning and chronic prevention are also [15].
4. One type of disaccharide found in moringa is that of saccharose. It serves the purpose of energy provision quickly, thus energy. it also helps regulate blood sugar levels, especially when included as part of a balanced diet and consumed in appropriate portions [16].
5. Phytosterols: Moringa plant is reported to contain phytosterols which are compounds similar to cholesterol and have benefits such as lowering levels of bad cholesterol (LDL) which may help to reduce the risk of heart disease. And helps to maintain a healthy body defenses due to its anti - inflammatory activity [17]. Therefore, the moringa plant's chemical properties are pleasant and health inspiring to utilize it as an ingredient for supporting health and preventing diseases. Also a moringa rich diet is very helpful in increasing energy as well as physical fitness.

All parts of Moringa oleifera (leaves, seeds, bark and roots) are used for therapeutic purposes, and are not exclusively intended for food . It constitutes a good dietary supplement for malnourished subjects and is positioned as a toning, strengthening and immune system stimulating product. Moreover, numerous therapeutic virtues are attributed to M. oleifera which is used in traditional medicine for the treatment of metabolic, inflammatory, infectious, parasitic and tumoral.

Table 2: The chemical composition of Moringa oleifera leaves Data per 100 grams of dry matte

Mineral	Dry Leaf
Macro-elements (%)	
Calcium (%)	3.65
Phosphorus (%)	0.30
Magnesium (%)	0.50
Potassium (%)	1.50
Sodium (%)	0.164
Sulphur (%)	0.63
Micro-elements (mg/kg)	
Zinc (mg/kg)	31.03
Copper (mg/kg)	8.25
Manganese (mg/kg)	86.8
Iron (mg/kg)	490
Selenium (mg/kg)	363.00
Boron (mg/kg)	49.93

2.2. Medicinal properties

Due to the high amount of healing copper it possesses, all this time, Moringa Oleifera has been appreciated in both orthodox and alternative medicines for many decades. Moringa contains certain minerals and chemical compounds that promote its many health benefits. The medicinal properties of moringa in detail and the contributions of these components towards the wellness of the plant are given below:

1. Antioxidants: One of the strong antioxidants in moringa leaves is Vitamin C which protects the cell from oxidation. Other substances like chlorogenic acid, a phenolic compound, also act to reduce the risks of such chronic diseases as cancer by balancing the levels of oxidative stress in the body. Antioxidants are critical in the prevention of heart diseases and diabetes because they help reduce the incidence of diseases caused by free radicals [18].
2. Antiinflamatories: It has been reported in studies that moringa components are rich in compounds such as quercetin which is known to possess anti-inflammatory properties. Hence, the consumption of moringa helps in managing inflammation in the body which is useful in patients with degenerative inflammatory conditions such as arthritis. [19].
3. Promoting the health of the immune system since moringa includes numerous vitamins and minerals that aid in the immune system's operation, such as vitamin C and A, which are essential for enhancing immunity. As a result, eating moringa can strengthen the body's defenses against illness and infection, making it a natural source of support for general health [20].
4. Improve heart health: The components found in Moringa contribute to improving heart health by, reducing levels of bad cholesterol (LDL) as the phytosterols contained in Moringa can help reduce cholesterol levels. Increasing blood pressure because moringa's potassium content is thought to have blood pressure-lowering effects. These characteristics aid in the prevention of heart disease and enhance cardiovascular health [21].
5. Controlling blood sugar levels: Research has indicated that the presence of chlorogenic acid and other chemicals in moringa may help reduce blood sugar levels. Consequently, it might benefit diabetics by assisting in controlling and regulating blood sugar levels [22].
6. It consists of many beneficial and skin-enhancing components such as fatty acids, which moisturize the hair, and vitamin E, which acts as a barrier to the skin. Moringa is of great importance to beauty care as it improves the fullness of hair and the quality of the skin [23].

Moringa can provide numerous health advantages, including, but not limited to, helping the immune system, reducing chronic inflammation, enhancing cardiovascular function, and regulating glucose levels, and can be incorporated into a healthy life-style for the promotion of health and wellbeing.

3. Mechanism of Effect of Moringa on Blood Sugar

Due to the blood sugar regulating and insulin sensitizing abilities of moringa oleifera, it is gaining popularity in the health research sector. The

patients suffering from diabetes and insulin resistance might have increased insulin sensitivity levels caused by the active ingredients found in moringa. Below we study the effect of moringa on insulin sensitivity and the mechanism of action of the active ingredients in details. [24].

3.1. Effect on insulin sensitivity

Insulin sensitivity refers to the extent to which the body can respond to the hormone insulin which facilitates the transport of glucose from the blood into cells for utilization as an energy source. Insulin resistance and type 2 diabetes may eventually result from the body producing more insulin to maintain blood sugar levels when this sensitivity declines [25]. Studies on persons who consume moringa have demonstrated changes in blood sugar levels and insulin responsiveness, which shows that consuming moringa extracts can increase insulin sensitivity. The therapeutic actions of moringa are disclosed by a range of active substances, including [26, 27]:

A. Iron, Vitamins, and Minerals: Zinc is a crucial component for enhancing the efficiency of cells that produce insulin. The pancreas secretes more insulin when zinc is present. Vitamins A and C, which are abundant in moringa, improve cell health and lower oxidative stress.
B. Amino Acids: The vital amino acids in moringa help the body produce more insulin, which facilitates the better extraction of glucose.
C. Compounds That Are Active: Chlorogenic Acid: regarded as one of the primary constituents of Moringa, studies have demonstrated that it lowers blood sugar levels by improving insulin sensitivity and decreasing intestinal absorption of glucose. Quercetin: An antioxidant flavonoid that has been shown to improve insulin secretion and lower inflammation.
D. Reducing Inflammation: Insulin sensitivity is adversely impacted by chronic inflammation. Quercetin and chlorogenic acid, two of the plant's active ingredients, aid in reducing inflammation, which enhances the body's reaction to insulin.

3.2. Reduce glucose production

The primary organ in the body that produces glucose through a process called gluconeogenesis is the liver. When the body requires energy during a fast or in between meals, this process takes place. Here, non-carbohydrate substances like lipids and amino acids are converted to glucose [28]. According to research, plants derived from the moringa plant can effectively reduce the liver's synthesis of glucose through a number of ways [29]:

A. Inhibition of gluconeogenesis enzymes: The active ingredients in moringa, including quercetin and chlorogenic acid, help to decrease the enzymatic activity of some liver enzymes linked to gluconeogenesis, including pyruvate kinase and phosphoinositide-carboxylase. It is possible to lower the quantity of glucose the liver produces by blocking these enzymes.
B. Increasing insulin sensitivity: Moringa makes peripheral tissues more sensitive to insulin, which helps the liver react to insulin more effectively. Blood glucose levels are lowered when the liver's gluconeogenesis is inhibited in response to an effective insulin response.
C. Inflammation reduction: Antioxidants and anti-inflammatory substances included in moringa help to lessen inflammation linked to insulin resistance. Reducing inflammation helps to improve liver function and lower the generation of glucose since chronic inflammation in the liver can also have a negative impact on gluconeogenesis.

3.3. Effect on insulin levels

Research suggests that moringa can significantly increase blood insulin levels. The following points can be used to summarize the primary impacts of moringa [30]:

A. Inducing the pancreas to secrete more insulin: The components found in moringa leaves, such as phenolic compounds and essential oils, are thought to induce the pancreatic beta cells to produce more insulin. This kind of stimulation improves blood sugar regulation and insulin secretion.
B. Increasing insulin sensitivity: Moringa enhances the responsiveness of cells in the body to insulin, thus increasing secretion of the hormone produced. This improvement serves to utilize glucose more efficiently so that there is a reduction in insulin resistance, which is often a characteristic of diabetes.
C. Antioxidant effect: Moringa is rich in antioxidants like vitamins C and E that play a significant role in protection against damage by free radicals. Appropriate management of oxidative stress levels positively affects the ability of the body to utilize insulin while also improving the response of the body's cells to insulin.

4. Previous Studies and Results

The study was based on the use of the Scopus database, which contained a set of reference studies. The re-search adopted an extensive synthesized

study design in collecting and analyzing data which resulted in the reference studies of this study.

4.1. The effectiveness of Moringa in reducing blood sugar:

In a trial conducted in 2020, moringa leaf powder was given to an investigational group of patients with type 2 diabetes. The results show the mechanisms by which the plant had a hypoglycemic effect, which involves inhibiting the enzymes glucosidase and amylase, increasing insulin secretion, and its sensitivity [31]. A group of diabetic individuals was also given Moringa powder in a research (2020) and the results suggested that moringa decreased blood glucose concentration levels [32]. In a trial (dated 2021) moringa leaves infusion was administrated to a group of type-2 diabetes patients daily for one week. The results indicated that the syrup made from Moringa leaves (Moringa oleifera) had an effect in lowering blood sugar levels of patients suffering from type 2 diabetes [33]. A report of research done in the year (2023) rotating around the tested effects of ingesting treated Moringa oleifera leaf powder in diabetic subjects showed that ($p < 0.05$) HBA1c glucose levels,dyslipidaemia parameters high equivalent (LDL-C) and low equivalent (HDL-C) were significantly altered in the treatment group. The powder was administered to patients on two occasions each day, after breakfast and at 7pm, for a total of 90 days [34]. In a study published in (2024), a group of patients with blood sugar levels between 140 and 199 mg/dL, ages 45 to 59, were given a mixture that included a decoction of the Moringa plant twice a day for seven days at a dose of 175 ml. The blood glucose levels significantly decreased, according to the findings [35].

4.2. The mechanism of action of moringa in reducing blood sugar

According to literature and past studies, moringa stimulates the pancreatic beta cells that produce more insulin, which is one of the ways it increases insulin release. Enhancing insulin sensitivity through lowering intestinal glucose absorption after meals, protecting the body from oxidative stress, and enhancing the body's cells' reaction to insulin, all of which enhance the health of insulin. A study (2011) examined the effects of oral dosages of 250 and 500 mg/kg of moringa extract on a group of diabetes patients. After 1–7 hours of injection, the blood glucose levels significantly decreased, according to the data [36]. In one of the research projects performed in 2016, the volunteers securely swallowed 0, 1, 2, and 4 grams sequentially increasing oral doses. The experiments showed that healthy subjects, when given very high doses (i.e. 4 g) powdered moringa leaf capsules, experienced enhanced release of insulin [37]. In a study (2016) focused on the anti-hyperglycemic effects of Moringa oleifera tea on volunteers blood glucose levels were collected every 30 minutes for 150 minutes. Drinking Moringa tea prior to a glucose challenge was associated with a smaller rise in blood sugar. [38]. In one of the experiments (2020) taken diabetic patients, an aliquot of plant extract 150 ml was given once daily for ten days. Since the water infusion contains flavonoids, and the infusion has a hypoglycemic effect, the study proved that it is able to reduce blood sugar levels [39].

5. Discussion

According to scientific studies, it seems that components from moringa such as isothiocy-anates and polyphenols are important when managing blood glucose levels. In some researchers conducted, taking supplements or leaves of Moringa has been shown to successfully reduce post-meal blood glucose levels, thus helping in the treatment of type 2 diabetes. It has also been shown in some experimental research that Moringa could probably change the sugar metabolism pathways of the human body, hence blood sugar levels among study participants were lower. Researchers have found that moringa can also be beneficial when it comes to insulin sensitivity which is essential when blood sugar levels need to be controlled. The chemical components of moringa promote the function of pancreatic beta cells, improving the body's tolerance to insulin. In studies examining the effects of moringa in patients with diabetes, a finding has also been made with regards improvement of insulin sensitivity which correlates with lower resistance to the hormone. In addition, laboratory studies have demonstrated that moringa also acts on insulin receptors – thus enhancing the action of insulin in penetrating cells with glucose. Furthermore, moringa has been found to enhance insulin production as well. Daily consumption of moringa has been shown in several studies to increase blood levels of insulin by stimulating beta cells of the pancreas. This further reinforces the existing view of modulating blood sugar by maintaining the physiological processes of the body. It is known that increased level of insulin in the blood curbs hyperglycemic levels and may even render anti-diabetic drugs useless. Enhancing the production and utilization of insulin in the cells is one of the crucial things that every diabetic management should covet. According to some studies, moringa

has been shown to inhibit the production of glucose by the liver which is crucial for individuals with high blood glucose levels. The Moringa components might inhibit some enzymes responsible for glucose biosynthesis such as phosphoenolpyruvate carboxykinase and glucose-6-phosphatase. It is evident that reducing the liver's production of glucose can be beneficial in the treatment of diabetes since this can result in better control of blood glucose levels.

6. Conclusions

Medicinal plants exhibit therapeutic properties as well as pharmacological activities due to the presence of bioactive compounds synthesized by these plants. This work has presented the biological activities of Moringa oleifera plant, particularly reducing blood sugar. Based on the recent evidence on moringa's health effects, this plant possesses essential elements such as vitamins, minerals, and amino-acids that reduce blood sugar levels and enhance sensitivity to insulin. Many clinical and analytical studies conducted demonstrate that using moringa can actually reduce blood glucose levels, which indicates its efficiency use in patients suffering form diabetes. However, one should always bear in mind how important it is to study the interaction of Moringa with other drugs. Studies suggest that additional research should be done to understand the effects of moringa on antihypertensives, antithyroid, and antidiabetic drugs. Due to the likelihood of incompatibility with various medications that would instead result into adverse phenomena, it is important that a physician is consulted before commencing the use of Moringa extract supplements. Furthermore, although moringa has its benefits, more studies are still urgently needed to to better understand the long-term effects of regular Moringa consumption on blood sugar regulation. Scientists should also explore how safe to use moringa for a long time, its compatibility with other drugs and the appropriate amounts to be administrated. It is demanded to carry out further research on Moringa oleifera plant to allow better understanding of its biological activities. This includes running histological studies for both pancreas and liver, so that biological effects of M. oleifera on tissues and cells are well understood. Additionally, it is valuable to both identify and characterize the chemical compounds that may influence the antidiabetic activity. Also, optimizing the extraction method and solvents used is highly required to maximize the contents of metabolites and consequently the therapeutic effect. Furthermore, conducting additional experiments on rats; in particular Psammomys obesus that presents physiological particularities of insulin secretion; is extremely useful to evaluate the antidiabetic activity of M. oleifera leaf extracts. Finally, justified incorporation of Moringa oleifera leaves into both synthesized Pharmaceuticals as well as into diet and food preparations of the population present interesting future studies.

Funding: No funding is received for this work.

Conflict of interest: The authors declare no conflict of interest, financial or otherwise.

References

[1] DECODE Study Group, and European Diabetes Epidemiology Group;" Is the current definition for diabetes relevant to mortality risk from all causes and cardiovascular and noncardiovascular diseases?". Diabetes Care, 26(3), 688-696. 2003.

[2] van der Aa; M. P.; Knibbe. C. A.; Boer. A. D.; van der Vorst. M. M.; "Definition of insulin resistance affects prevalence rate in pediatric patients: a systematic review and call for consensus". J. Pediatr. Endocrinol. Metab., 30(2), 123-131. 2017.

[3] Collier, J.J.; Hsia, D.S.; Burke, S.J.; "From pre-clinical efficacy to promising clinical trials that delay Type 1 diabetes". Pharmacol. Res. 208: 107342, 2024.

[4] Meier. C.; Schwartz. A. V.; Egger. A.; Lecka-Czernik, B.; "Effects of diabetes drugs on the skeleton". Bone 82: 93-100, 2016.

[5] Robinson. D.J.; Coons. M.; Haensel. H.; Vallis. M.; Yale. J.F.; "Clinical Practice Guidelines Expert CommitteeDiabetes and mental health". Can. J. Diabetes 42: S130-S141, 2018.

[6] Ríos, J.L.; Francini, F.; Schinella, G.R.; "Natural products for the treatment of type 2 diabetes mellitus." Planta Med. 81(12/13): 975-994, 2015.

[7] Kasole. R.; Martin. H.D.; Kimiywe. J.; "Traditional medicine and its role in the management of diabetes mellitus patients' and herbalists' perspectives". J. Evidence-Based Complementary Altern. Med. 2019(1): 2835691, 2019.

[8] Vivó-Barrachina. L.; Rojas-Chacón. M.J.; Navarro-Salazar. R.; Belda-Sanchis. V.; Pérez-Murillo. J.; Peiró-Puig. A.; "The role of natural products on diabetes mellitus treatment: A systematic review of randomized controlled trials". Pharmaceutics 14(1): 101, 2022.

[9] Mutar. Y.S.; Al-Rawi. K.F.; Mohammed, M.T.; "Moringa oleifera: Nutritive importance and its medicinal application, as a Review". Egypt. J. Chem. 64(11): 6827-6834, 2021.
[10] Prajapati.C.; Ankola. M.; Upadhyay. T.K.; Sharangi. A.B.; Alabdallah. N.M.; Al-Saeed. F.A.; Saeed, M.; "Moringa oleifera: Miracle plant with a plethora of medicinal, therapeutic, and economic importance". Acta Hortic. 8(6): 492, 2022.
[11] Abdull Razis. A. F.; Ibrahim. M. D.; & Kntayya. S. B.; "Health benefits of Moringa oleifera" Asian Pac. J. Cancer Prev. 15(20), 8571-8576. 2014.
[12] Milla. P. G.; Peñalver, R., and Nieto, G. "Health benefits of uses and applications of Moringa oleifera in bakery products." Plants, 10(2), 318. 2021.
[13] Abbas. R. K.; Elsharbasy. F. S.; and Fadlelmula. A. A.; "Nutritional values of Moringa oleifera, total protein. Amino acid, vitamins, minerals, carbohydrates, total fat and crude fiber, under the semi-arid conditions of Sudan." J. Microb. Biochem. Technol, 10, 56-58. 2018.
[14] Sodamade. A.; Owonikoko.A. D.; and Owoyemi. D. S. ;"Nutrient contents and mineral composition of Moringa oleifera Seed" Int. J. Chem. Stud. 5(2), 205-207. 2017.
[15] Hassan. M. A.; Xu, T.; Tian, Y.; Zhong, Y.; Ali, F. A. Z.; Yang, X.; and Lu, B.; "Health benefits and phenolic compounds of Moringa oleifera leaves: A comprehensive review" Phytomedicine, 93, 153771. 2021.
[16] Metsopkeng, C. S.; Nougang, M. E.; Arfao, A. T.; Perrière, F.; Moungang, L. M.; Ewoti, O. V. N.; and Nola, M. ;"Minimum inhibition and bacterial concentrations of the plant Moringa Oleifera extracts against the bacteria Escherichia coli and Staphylococcus aureux" Bacterial Empire. hal-03865237 , vol.5, No.4version 1 (23-11-2022).
[17] Talreja, T.;and Goswami, A. ;"Phytosterols production in Moringa oleifera in vitro cultures" European Journal of Biotechnology and Bioscience, 4(1), 66-69. 2016.
[18] Shalaby, E. A.; Shanab, S. M.; El-Raheem, W. M. A.; and Hanafy, E. A.; "Biological activities and antioxidant potential of different biosynthesized nanoparticles of Moringa oleifera" Sci. Rep., 12(1), 18400. 2022.
[19] Islam, Z.; Islam, S. R.; Hossen, F.; Mahtab-ul-Islam, K.; Hasan, M. R.; and Karim, R.; " Moringa oleifera is a prominent source of nutrients with potential health benefits" Int. J. Food Sci., (1), 6627265. 2021
[20] Islam, Z.; Islam, S. R.; Hossen, F.; Mahtab-ul-Islam, K.; Hasan, M. R.; and Karim, R. ; "Moringa oleifera is a prominent source of nutrients with potential health benefits" Int. J. Food Sci. 2021(1), 6627265. 2021.
[21] Alia, F.; Putri, M.; Anggraeni, N.; and Syamsunarno, M. R. A. A.; "The potency of Moringa oleifera Lam. as protective agent in cardiac damage and vascular dysfunction" Front. Pharmacol. 12, 724439. 2022.
[22] Nova, E.; Redondo-Useros, N.; Martínez-García, R. M.; Gómez-Martínez, S.; Díaz-Prieto, L. E.; and Marcos, A.; "Potential of Moringa oleifera to improve glucose control for the prevention of diabetes and related metabolic alterations: a systematic review of animal and human studies" Nutrients, 12(7), 2050. 2020.
[23] Garg, P.; Pundir, S.; Ali, A.; Panja, S.;Chellappan, D. K.; Dua, K.; and Negi, P.; "Exploring the potential of Moringa oleifera Lam in skin disorders and cosmetics: nutritional analysis, phytochemistry, geographical distribution, ethnomedicinal uses, dermatological studies and cosmetic formulations" Naunyn-Schmiedeberg's Arch. Pharmacol., 397(6), 3635-3662. 2024.
[24] Amelia, D.; Santoso, B.; Purwanto, B.; Miftahussurur, M.; and Joewono, H. T.; "Effects of Moringa oleifera on insulin levels and folliculogenesis in polycystic ovary syndrome model with insulin resistance." Curr. Med. Chem.:Immunol., Endocr. Metab. Agents18(1), 22-30. 2018.
[25] Mohamed, M. A.; Ahmed, M. A.; and El Sayed, R. A.; "Molecular effects of Moringa leaf extract on insulin resistance and reproductive function in hyperinsulinemic male rats." J. Diabetes Metab. Disord. 18, 487-494. 2019.
[26] Waterman, C.; Rojas-Silva, P.; Tumer, T. B.;Kuhn, P.; Richard, A. J.; Wicks, S.; and Raskin, I.; "Isothiocyanate-rich Moringa oleifera extract reduces weight gain, insulin resistance, and hepatic gluconeogenesis in mice." Mol. Nutr. Food Res., 59(6), 1013-1024. 2015.
[27] Siahaan, S. C. P.; Santoso, B.; and Widjiati. ;"Effectiveness of Moringa oleifera leaves on TNF-α expression, insulin levels, glucose levels and follicle count in Rattus norvegicus PCOS model." Diabetes, Metab. Syndr. Obes.: Targets Ther., Volume 11, Issue 11 3255-3270. 2022.
[28] Sosa-Gutiérrez, J. A.; Valdéz-Solana, M. A.; Forbes-Hernández, T. Y.; Avitia-Domínguez, C.

I.; Garcia-Vargas, G. G.; Salas-Pacheco, J. M.; and Sierra-Campos, E.; "Effects of Moringa oleifera leaves extract on high glucose-induced metabolic changes in HepG2 cells." Biology, 7(3), 37. 2018.

[29] Leone, A.; Bertoli, S.; Di Lello, S.; Bassoli, A.; Ravasenghi, S.; Borgonovo, G.; and Battezzati, A.; "Effect of Moringa oleifera leaf powder on postprandial blood glucose response: In vivo study on Saharawi people living in refugee camps." Nutrients, 10(10), 1494. 2018.

[30] Vargas-Sánchez, K.; Garay-Jaramillo, E.; and González-Reyes, R. E.; "Effects of Moringa oleifera on glycaemia and insulin levels: A review of animal and human studies." Nutrients, 11(12), 2907. 2019.

[31] Haber, S. L.; McMahon, R. P.; Barajas, J.;Hayes, A. R.; and Hussein, H.; "Effects of Moringa oleifera in patients with type 2 diabetes." Am. J. Health-Syst. Pharm. 77(22), 1834-1837. 2020.

[32] Owens III, F. S.; Dada, O.; Cyrus, J. W.; Adedoyin, O. O.; and Adunlin, G.; "The effects of Moringa oleifera on blood glucose levels: a scoping review of the literature." Complement Ther. Med, 50, 102362. 2020.

[33] Angraini, S. S.; Ibrahim, I.; Jesica, F.; and Hayu, R.; "The Effect of Decoction of Moringa Leaves (Moringa Oleifera) on Blood Sugar Levels in Type II Diabetes Mellitus Patients." In 2nd Syedza Saintika International Conference on Nursing, Midwifery, Medical Laboratory Technology, Public Health, and Health Information Management (pp. 88-91). Atlantis Press. University in Palembang, Indonesia SeSICNiMPH 2021. 2021, October.

[34] Henouda, S.; Karouche, S.; Attou, A.; and Boulal, A.; "Study of the effect of Moringa oleifera leaves powder in Southwestern Algerian diabetic patients: a pilot clinical trial. "Not. Sci. Biol. 15(2), 11554-11554. 2023.

[35] Ananda Pratama Putra, B. Z.; Maigoda. T. C.; and Suryani. D. ; "the effect of soy milk with boiled moringa leaves on blood sugar levels in type 2 diabetes mellitus patients: study in Bengkulu, Indonesia." National Nutrition Journal/Media Gizi Indonesia, 19. 2024.

[36] Tende, J. A.; Ezekiel, I.; Dikko, A. A. U.; and Goji, A. D. T.; "Effect of ethanolic leaves extract of Moringa oleifera on blood glucose levels of streptozocin-induced diabetics and normoglycemic Wistar rats." Br. J. Pharmacol. Toxicol., 2(1), 1-4. 2011.

[37] Anthanont, P.; Lumlerdkij, N.; Akarasereenont, P.; Vannasaeng, S.; and Sriwijitkamol, A.; "Moringa oleifera leaf increases insulin secretion after single dose administration: a preliminary study in healthy subjects." J. Med. Assoc. Thail, 99, 308-313. 2016.

[38] Fombang, E. N.; and Saa, R. W.; "Antihyperglycemic activity of Moringa oleifera Lam leaf functional tea in rat models and human subjects." Food Nutr. Sci. 7(11), 1020. 2016.

[39] Dafriani, P.; Karamika, M.; Anggraini, S. S.; Marlinda, R.; "The Potential of Noni (Moringa citrifolia) in Lowering Blood Glucose Levels in Diabetes Mellitus Patients group". Bio. Edu. Sci. 199(88), 37-441. 2020.

[40] Huang, Q.; Liu, R.; Liu, J.; Huang, Q.; Liu, S.; Jiang, Y.; "Integrated network pharmacology analysis and experimental validation to reveal the mechanism of anti-insulin resistance effects of Moringa oleifera seeds." Drug Des., Dev. Ther. issue 2; volume 14:4069–4084. doi: 10.2147/DDDT.S265198. Oct 2020.

[41] Gómez-Martínez, S.; Díaz-Prieto, L.E.; Castro, I.V.; Jurado, C.; Iturmendi, N.; Martín-Ridaura, M.C.; Nova, E.; "Moringa oleifera leaf supplementation as a glycemic control strategy in subjects with prediabetes." Nutrients, 14(1), 57. 2021.

[42] Hamza, M.A.; Naimuzzaman, M.; Roy, S.K.; "Health benefits of Moringa oleifera: Used as an anti-diabetic agent." IJARIT, 13(1), 96-102. 2023.