Exploring Sudanese Medicinal Plants for their Antidiabetic and Hypolipidemic Benefits: A Review

Amna MohammedAli Mustafa[1], Ogail Yousif Dawod[2*], Reem Alzaki Mohammed[3], Ahmed M. Alfaki[4], Sitelbanat Osman Mohamed Ahmed[5], Mohamed H. Abdelrahman[6], Raga Mohamed[7], Mohamed M Almaki[8], Boshra Mozaffar[9], Abrar Alshahrani[10], Mohammed F. Bajahzer[11], Faiza Abdalla Saeed Khiery[12]

1. *Assistant Proffesor, Department of Nursing, College of Nursing and Health Sciences, Jazan University, Saudi Arabia. Email: ammustafa@jazanu.edu.sa*
2. *Assistant Professor of Physiology, Physical Therapy Department, College of Nursing and Health Sciences, Jazan University, Jizan, Saudi Arabia. E-mail: odawod@jazanu.edu.sa, ORCID: https://orcid.org/my-orcid?orcid=0000-0002-4439-0173*
3. *Ministry of Health - Jizan Health Cluster, Saudi Arabia. E-mail: reemalzaki77@gmail.com*
4. *Assistant Professor, Physical Therapy Department, College of Nursing and Health Sciences, Jazan University, Jizan, Saudi Arabia. E-mail: aelfaki@jazanu.edu.sa*
5. *Department of Nursing, College of Nursing and Health Sciences, Jazan University, Saudi Arabia. Email: Sitoossman@yahoo.com, ORCID: https://orcid.org/0000-0001-7787-1283*
6. *Lecturer Of Histology, College of Nursing and Health Sciences, Medical Laboratory Technology, Jazan University, Saudi Arabia. Email: mhashim@jazanu.edu.sa*
7. *Lecturer of cardiothoracic nursing, Department of Nursing, College of Nursing and Health Sciences, Jazan University, Saudi Arabia. Email: mreja@jazanu.edu.sa*
8. *Department of Medical Laboratory Technology, College of Nursing and Health Sciences, Jazan University, Saudi Arabia. Email: Malmaki@jazanu.edu.sa , ORCID: 0009-0000-8285-084X*
9. *College of Nursing and Health Sciences, Clinical Nutrition Department, Jazan University, Saudi Arabia. Email: Bmozaffar@jazanu.edu.sa. ORCID: https://orcid.org/0009-0001-6054-7046*
10. *College of Nursing and health Science, Jazan University, Saudi Arabia. Email: Afalshahrani@jazanu.edu.sa*
11. *College of Nursing and Health Sciences, Clinical Nutrition Department, Jazan University, Saudi Arabia. Email: (mfbajahzer@jazanu.edu.sa). ORCID: 0000-0002-5244-299X*
12. *Assistant professor , Department of Public health, College of Nursing and Health Sciences, Jazan University, Saudi Arabia. Email: Fkheiry@jazanu.edu.sa*

***Correspondence author: Ogail Yousif Dawod, Email: odawod@jazanu.edu.sa**

KEYWORDS

Antidiabetic, Medicinal plants, Flavonoids, Polyphenols, Lipid absorption

ABSTRACT

Diabetes mellitus and associated lipid disorders are major threats to the public health in the global societies and particularly in the developing countries where synthetic medications are not easily available. This review aims to determine various Sudanese medicinal plants and their effects on antidiabetic and hypolipidemic properties, which are vital parts of the research since Sudan is endowed with diverse bio and ethnomedical resources. The article conduct a systematic review of the literature in order to examine the plants that can be used to treat diabetes and lipid profile in a scientific manner. The specific phytochemicals mentioned include flavonoids, alkaloids, saponins, and polyphenols for their bioactivities.

Furthermore, the ways through which the action of these drugs influence glucose homeostasis, insulin release, and lipid absorption are also reviewed. Some important findings recommend that a number of Sudanese medicinal plants have a potent antidiabetic and hypolipidemic potency, which may be a blend of flavonoids, alkaloids, and terpenoids bioactive compounds were proposed to be accountable. The data given in the review might be valuable for a comprehensive evaluation of the therapeutic efficacy of these plants as new sources of natural drugs for the treatment of diabetes and dyslipidemia and an illustration of how traditional experience might be translated into the terms of modern pharmacology. This review also recognizes research limitations calling for more rigorous clinical trials to substantiate the efficacy and safety of these medicinal plants.

1. Introduction

Diabetes mellitus and dyslipidemia are two main non-communicable diseases that worsen the quality of life and play a major role in global morbidity and mortality (Chen, 2021). Seeing the rising trend of diabetics in the global population, the need to seek for efficient and economical methods of managing the condition cannot be over-emphasized. Herbal remedies have for long remained the cornerstone of preventive and curative health care systems of a given society and are therefore the source of a potential pool of bioactive compounds. Some of the objectives of such investigations include; Sudan, known for its rich ethnobotanical resources, which serves as a suitable ground for such research studies (Elhassaneen, 2015).

Sudan's geographic and climatic conditions support the growth of numerous plant species, some of which have been used locally to treat assorted conditions, including metabolic diseases. Sudanese communities, over the years, have used plants within their social setting to cure diseases and ailments, therefore, possessing rich traditional knowledge on the effectiveness of local plants (Georgekutty, 2015). Nevertheless, due to this widespread traditional use, the scientific evidence on the efficacy of these plants in managing diabetes and its related complications, particularly in terms of their antidiabetic and hypolipidemic effects, is still scarce.

This review will seek to comprehensively and systematically review research on Sudanese medical plants with claimed antidiabetic and hypolipidemic properties. In doing so, it aims at placing traditional knowledge alongside modern scientific research and thus, explore the role of these plants in the present and future medical approaches. Not only does this compilation provide a basis for subsequent pharmacological research, but it also highlights the role of ethnobotanical information and species conservation (Maghraby, 2022).

Given the current issues with drug resistance, side effects, and enormous costs of conventional treatments for diabetes and dyslipidemia, research on natural remedies is timely and relevant. The natural bioactive compounds present in medicinal plants present a potential approach to expanding therapeutic invention that is affordable and effective (Nwoga, 2023). Moreover, assessing the ways by which these plants cause their effects could help in further identifying molecular targets for metabolic diseases.

The present review aims at presenting the principal Sudanese medicinal plants with antidiabetic and antidyslipidemic properties in terms of phytochemistry, mechanisms of action, and published

findings. Some of the likely issues and prospects to be touched in relation to the use of these natural resources are; sustainable exploitation and conservation, and the call for interdisciplinary approaches that will blend the conventional and the orthodox medicinal systems.

This review aimed at describing the antidiabetic and hypolipidemic properties of Sudanese medicinal plants; the author suggests tips on how more research can be conducted and more information gathered about how these plants can be used to enhance health and cure numerous diseases due to its potential in metabolic diseases cure.

2. Literature Review

Some of the Sudanese medicinal plants have been studied for their potential role in managing diabetes. For instance, Sabiu (2019) carried out a study on the effectiveness of *Hibiscus sabdariffa* L. which is a plant commonly used in Sudanese traditional medicinal practice for managing diabetes. The results of the study indicated that the aqueous extract of Hibiscus sabdariffa possess antidiabetic properties from the research done on the diabetic rats where it brought down their blood glucose level.

Another considerable piece of work by Yusuf (2023) was employed to overview the hypoglycemic efficacy of *Moringa oleifera Lam*, a plant also known as the drumstick tree. The study established that the Moringa oleifera leaf extract led to lowered blood glucose level in rats with diabetes induced by streptozotocin. The reasons for its effectiveness were explained by flavonoids and phenolic acids that were shown to stimulate secretion of insulin and increase its sensitivity.

A research survey conducted by Wali (2022) indicated that Neem leaf extract contains antidiabetic properties due to compounds such as *nimbidin* and *quercetin* which possess hypoglycemic properties. The study also noted that Neem could be used to control blood glucose levels and encouraged for more clinical research into its application for diabetic treatment.

Similar findings were also revealed in a study carried out by Salehi (2019) where it was shown that the aqueous extract of Baobab leaves reduced the blood glucose concentrations of diabetic mice. The study found that the content of dietary fibers and polyphenols in Baobab was relatively higher and they could have contributed to the antidiabetic effects. Further investigation into the effects of this plant have also found that it aids in glycemic control and the improvement of insulin sensitivity as a result of its antioxidant composition and soluble fiber content.

Moreover, the antihyperlipidemic potential of Sudanese medicinal plants has been a subject of several studies. Using a diabetic or cardio-vascular disease: Complications can include high cholesterol and triglyceride levels. Some of the tropical plants in Sudan have also been confirmed to have the potential of combating lipid levels; therefore, enhancing the existing strength of managing diabetes. According to Ojelere (2014), a study on the resin extract of Commiphora myrrha revealed that this plant has potential hypolipidemic properties after conducting the experiment on hyperlipidemic rats. The findings of the study showed that the extract lowered the overall level of cholesterol, LDL-cholesterol, and triglycerides and increase the HDL cholesterol levels. These effects were said to have been influenced by the steroidal saponins and essential oils in myrrh.

Based on a study undertaken by El-D Ndarubu (2019) found that with the increase in total cholesterol, LDL cholesterol, and triglycerides in hyperlipidemic subjects proved that administering Nigella sativa oil lowered those levels. Thymoquinone, one of the principal bioactive constituent of N. nigrum, was suggested to elicit the lipid-lowering effects due to antioxidant and anti-inflammatory activities.

A plethora of studies have been compiled by Miaffo in (2020) to highlight that Fenugreek indeed has the potential to enhance lipid profile in diabetic and hyperlipidemic models. The review made it clear that soluble fibre content and steroidal saponin found in Fenugreek seeds are beneficial in inhibiting cholesterol absorption and regulating lipid profile. Some current research efforts have been directed to the synergistic interaction of more than one Sudanese traditional medicine for improving the combined antidiabetic and hypolipidemic effects. For instance, Gang, in a study in 2023, assessed the comparative impact of Hibiscus sabdariffa and Nigella sativa, in diabetic rats and revealed that the combined impact of Hibiscus sabdariffa and Nigella sativa had a more pronounced and statistically significant improvement on blood glucose levels as well as the lipid profile than the individual plants. This opens up chances to discover other combinatory herbal compositions for diabetes and hyperlipidemia.

3. Methodology

3.1 Literature Search Strategy

The present review was carried out through a systematic search in databases such as PubMed, Scopus, Web of Science, and Google Scholar. The literature search was conducted for the following keywords and phrases: “Sudanese medicinal plants” “antidiabetic” “hypolipidemic” properties, “ethnobotanical research in Sudan,” “phytochemical,” and “traditional medicine.” Only articles published in English by October 2023 were considered. The reference lists of the identified articles were also manually perused to find other related articles. Textbooks, ethnobotanical surveys and government publications were also used where necessary.

3.2 Inclusion and Exclusion Criteria

Inclusion criteria for the selection of articles included: (i) published articles in PubMed that investigated the medicinal plants used in Sudan for diabetes or lipid disorders; (ii) experimental research that evaluated the efficacy of the plants in controlling diabetes or lipid disorders using in vitro, in vivo, or clinical approaches; and (iii) papers that highlighted the phytochemical profiles of these plants. Exclusion criteria incorporated: (i) researches which are not grounded in medicinal plants from Sudan; (ii) articles which do not relate to diabetes or lipid metabolism; and (iii) researches with missing or ambiguous data.

3.3 Data Extraction and Synthesis

Information from the chosen papers was carefully collected with the help of special tables and forms. These included the plant name, its common name, plant part to be used, the preparation method, and the recommended dosage. Furthermore, information regarding the study type, biological assays used, animals or human subjects involved, and the reported results were captured. Also recognized was phytochemicals that exist and supposed mode of working In addition to phytochemical contents there are also the confirmed effects that were highlighted as follows; The collected data were integrated into an organized framework to give a logical progression of the

previous state of research regarding the antidiabetic and hypolipidemic aspects of Sudanese medicinal plants.

3.4 Data Integration and Analysis

The data collected from all the sources was compiled and used to generate the current situation of antidiabetic and hypolipidemic activities of Sudanese medicinal plants. Hence, a qualitative synthesis approach was undertaken to assess the results of each study, and, where possible, a metric-based evaluation of efficacy was included. Comparative analysis was also done to establish which plant was more effective in preclinical and clinical trials.

For studies involving phytochemical constituents, the extraction, isolation, and identification techniques as used in the various studies were considered. Especially, the conventional methods like high-performance liquid chromatography (HPLC), gas chromatography-mass spectrometry (GC-MS), and nuclear magnetic resonance (NMR) spectroscopy were focus on due to its reliability and reproducibility. Several phytochemicals with antidiabetic and hypolipidemic properties were identified and described based on the available information regarding their biochemical activities and actions.

3.5 Limitations

Despite the strengths of this review, there are limitations that include but are not limited to publication bias, heterogeneity in terms of study design and quality of reporting. Further, there is a consensus that the search was only conducted in English language databases and thus, there is a possibility of having missed noteworthy literature written in other languages. It is also not possible to draw clear conclusions from the study as the data is heterogeneous, the methodologies of the studies are dissimilar, and the sample sizes also vary. Finally, a noteworthy limitation is the use of traditional knowledge which may be diverse according to the anthropological and regional status of the study and thus have an effect on the reproduction of the results.

3.6 Ethical Considerations

Ethical issues were taken into consideration at each stage of the review process. Secondary data did not require ethical permission for its use. However, one thing that the review fully complied with in respect of the intellectual property rights was that all the sources used were duly cited and traditional knowledge systems were recognized. Moreover, it aimed at acknowledging the bioprospecting legislation and the rights of communities in order to safeguard their knowledge systems that brought about the benefit of such research.

4. Findings and Discussion

4.1 Overview of Sudanese Medicinal Plants

4.1.1 Description of Botanical Species

Sudan with its vast geographical and climatic variation harbors a diverse and vast array of medicinal plants that are widely used in traditional health care practices. In our research, we managed to uncover more than 150 plants with antidiabetic and hypolipidemic properties. These are core classifications from such families as *Fabaceae, Asteraceae, Lamiaceae, and Apiaceae*.

Fabaceae Family: Some of the species contained in this family include; *Acacia nilotica, Prosopis chilensis*. *Acacia nilotica* contains versatile medicinal uses with multiple significant pharmacological actions like antidiabetic and hypolipidemic agents. Other research works have

explained that it has an abundance of polyphenolic compounds that enhances its medical properties (Miaffo, 2020).

Asteraceae Family: Some of the common plants belonging this family are Vernonia amygdalina and Artemisia absinthium. In agreement with Ndarubu (2019), Vernonia amygdalina has been credited for detoxifying and enhancing insulin levels.

Lamiaceae Family: Members within this category include *Ocimum basilicum* and *Salvia officinalis*. *Ocimum basilicum* also known as basil is rich in antioxidants and has been reported to possess the ability to modulate blood glucose levels (Ojelere, 2014).

Apiaceae Family: *Cuminum cyminum* (cumin) as well as *Coriandrum sativum* (coriander) have been known for their hypolipidemic effects. These plants contain essential oils that Oshazi noted have shown distinct lipid-lowering and antihyperglycemic properties (Salehi, 2019).

4.1.2 Traditional Uses and Ethnobotanical Information

Traditional medicine in Sudan relies more on culture and practices that may have been inherited for generations. All these plant-based remedies are part of the health systems of several communities in Sudan and are utilized because they are easily available and relatively cheap.

Traditionally, the pods and bark of Acacia nilotica have been used in decoctions and infusions as antidiabetic agent and for curing complications arising from diabetes. These formulations have been passed down through generations, and the traditional healers use these formulations, alongside the beliefs of the communities on the formulations' effectiveness (Wali, 2022).

The ethnobotanical studies reveal that Vernonia amygdalina has been used by the primitive inhabitants for the management of diabetes and as an immunostimulant. According to Omonu et al. (2018) in Ethiopia traditional knowledge it helps in regulating blood sugar if chewed or brewed into tea; this was confirmed by Elbashir (2018) who observed blood glucose reduction in the experiment models.

Basil came out strongly as one of the most frequently used plants in traditional medicine among the Sudanese. It is where it is applied when preparing teas or infusions for treating diverse complications including diabetes and even cardiovascular diseases. These practices are part and parcel of the life of people in Sudan due to the availability of natural products among them. These traditional uses find contemporary scientific substantiation in studies more recent, which corroborate basil's antihyperglycemic efficacy (Chen, 2021).

Cuminum cyminum (cumin) and Coriandrum sativum (coriander) seeds are parts of daily food consumption and traditional therapeutic systems in Sudan. Other than for cooking, they are normally crushed and consumed for treating raised cholesterol and glycemic index. The rationale for this practice is supported by various research demonstrating their potential to modulate lipid levels and enhance glycemic management (Almoshari, 2022).

The complexity of the use of medicinal plants in Sudan to treat antidiabetic and hypolipidemic diseases demonstrates ethnomedicine as a connection between cultural legacy and contemporary medical care (Ahmed, 2022). The conclusions drawn from this review not only corroborate

folkloric evidence regarding these plants, but also underscore the discovery of novel therapeutic entities from these gifted natural resources.

Numerous studies support the pharmacological actions of these Sudanese plants. For example, it has been demonstrated by Alam (2018) that Acacia nilotica possessed antidiabetic activity in vivo using diabetic rats and confirmed significant hypoglycemic activity. Likewise, another study revealed that Vernonia amygdalina reduces blood glucose concentrations and lipid profile as per the study of Choudhari (2023).

Additionally, Ocimum basilicum has been proved to possess antihyperglycemic effects in various research studies. For instance, Yusuf (2023) in his research showed that preparations of basil helped to lower blood sugar and lipid concentrations in diabetic rats, affirming folk beliefs of the herbal medicine.

Not only are these plants edible spices but they also possess therapeutic properties Cuminum cyminum and Coriandrum sativum. The most investigated hypolipidemic essential oils are their oils. As found by Salama (2021) supplementation of cumin extract led to a decrease in total cholesterol and triglyceride levels Similarly, another research conducted by Salehi (2019) also suggested that coriander had hypolipidemic effects.

However, these results open the foundation for clinical studies to further examine the effects of these plants for medicinal usage. Though the ancient use is quite reliable, the contemporary scientific support is vital for the further adaption of these plants in the current system of medicine (Reddy, 2021).

Peculiarly, the ethnobotanical analysis suggests not only the pharmacological perspective but also the social and cultural aspects of the plant use in Sudan. These plants, accepted as natural remedies by the communities, are synonymous with empirical wisdom intermingled with shared cultural beliefs that have sustained people over successive generations (Obakiro, 2023).

4.2 Phytochemical Constituents of Sudanese Medicinal Plants

4.2.1 Common Bioactive Compounds

The Sudanese Medicinal Plants contain a rich number of phytochemical constituents, responsible for their therapeutic effects with special reference to antidiabetic and hypolipidemic effects. Substances constituting bioactivity include alkaloids, flavonoids, saponins, tannins, terpenoids and phenolic acids (Ndarubu, 2019).

For example, Cassia senna that has been used extensively in Sudanese traditional medicine is rich in flavonoids and anthraquinones. These compound have been shown to exhibit anti-oxidative effects which are crucial in managing oxidative burden associated with diabetes and hyperlipidemia. Likewise, Hibiscus sabdariffa (karkade) holds anthocyanins, flavonoids, and phenolic acids with antidiabetic and lipid-lowering effects in literature (Maghraby, 2022).

In a related study, Hasan (2016) showed that flavonoids extracted from Acacia nilotica exhibited hypoglycemic effect which is in accordance to what other related studies have proposed that flavonoids have antidiabetic property (Gang, 2023). Furthermore, fenugreek seed associated with Trigonella foenum-graecum has been reported to consist of diosgenin, steroidal saponin that works on glycemic load and lipid profile (Elhassaneen, 2015).

4.2.2 Mechanisms of Action

The active constituents of these Sudanese medicinal plants used in the management of diabetes and lipid disorders exhibit the following mechanisms.

Some of the ways through which this is achieved include the promotion of insulin release and function. For instance, some compounds called flavonoids derived from Cassia senna enhance insulin secretion from the pancreatic β-cells besides enhancing the insulin receptor sensitivity (Djiazet, 2021). A recent study revealed that the flavonoids in Hibiscus sabdariffa helped the muscle cells to take up glucose more effectively, thus helping regulate blood sugar (Chen, 2021).

In communication to hypolipidemic action, these phytochemicals usually work by controlling lipid metabolism through changes in enzyme activity involved in lipid synthesis and degradation. Steroid saponin Diosgenin present in Trigonella foenum-graecum fenugreek helps in lowering the blood lipids since it reduces the activity of HMG CoA reductase enzyme which is involved in formation of cholesterol (Alam, 2018). Furthermore, research has shown that saponins from Moringa oleifera promotes the expulsion of bile acids through the enhancement of their conjugation by preventing the reabsorption of these acids in the GIT hence by the use of cholesterol to form more bile acids in the liver to attain the required levels, the blood cholesterol levels decreases (Azab, 2023).

The final potential mechanism through which these phytochemicals work is antioxidation, or the reduction of oxidative stress. Phenolic acids and flavonoids have the ability to scavenge free radicals and prevent oxidative stress on pancreatic β-cells and other tissues by minimizing glycemic fluctuations and lipid peroxidation. Other work investigating the impacts of Adansonia digitata (baobab) revealed that the phenolic constituents exert antioxidant properties through preventing high glucose-induced oxidative stress in both in vivo and in vitro models (Ahmed, 2022).

Moreover, the anti-inflammatory properties of these compounds are also very much useful. Chronic inflammation is strongly associated with insulin resistance and hyperlipidemia. Flavonoids present in Hibiscus sabdariffa were found to suppress critical pro-inflammatory signals like NF-kB and improve metabolic rates (Almoshari, 2022).

4.3 Antidiabetic Benefits of Sudanese Medicinal Plants

4.3.1 Preclinical Studies (In Vitro and Animal Studies)

Many preclinical research works involving different Sudanese medicinal plants have been carried out for their antidiabetic effect using in vitro and animal experimental models. For example, the aqueous extract of Adansonia digitata (baobab) was found to reduce the fasting blood glucose concentrations in alloxan-induced diabetic rats through glucoregulatory mechanisms (Boukandou, 2019). Another study done on Moringa oleifera also suggested that the plant has significant antidiabetic properties including α-glucosidase preventing property and enhanced insulin receptor sensitivity in the mice fed with high fat diet (Choudhari, 2023). Vernonia amygdalina and Hibiscus sabdariffa also possessed tremendous hypoglycemic activity in the STZ induced diabetic rats confirming the efficacy of Sudanese plants in the treatment of diabetes (Elbashir, 2018; Farag, 2014).

Beside glycemic regulation, some Sudanese plants were also effective in attenuation of secondary diabetic complications like oxidative stress and inflammation. For instance, the methanolic extract

of Nigella sativa (black seed) has not only an antidiabetic activity but also possessed antioxidant potential in diabetes-induced rats due to abdominal reducing effects of oxidative stress markers in the experimental animals (Georgekutty, 2015). The results obtained in this research corroborate past investigations regarding other traditional medicinal plants underpinning a promising role for phytochemicals in the control of diabetes.

4.3.2 Clinical Trials and Human Studies

As for clinical trials and human subjects, information on the Sudanese medicinal plants is still rather limited. Despite this, there have been some encouraging signs. A clinical trial involving 20 type 2 diabetic patients from Sudan showed that consumption of M. oleifera leaf powder for three months had a substantial positive impact on fasting blood glucose as well as postprandial blood glucose levels (Miaffo, 2020). This is in concordance with other human experiments which were undertaken outside Sudan and where Moringa oleifera has equally presented glucose lowering influence (Ndip, 2013).

Furthermore, ethnopharmaceutical research and studies reveal that a mixture of Hibiscus sabdariffa and Ziziphus spina-christi is commonly employed by traditional healers in the management of diabetes. This traditional approach has rarely been captured in clinical contexts, although patient testimonies point to perceived improvements in glycemic control (Nwoga, 2023). Systematic clinical trials on Adansonia digitata have not been performed till date, yet several studies indicate that the future of this plant in clinical use is bright.

4.3.3 Mechanisms of Antidiabetic Action

The tested Sudanese medicinal plants targeting diabetes exert their antidiabetic effects through several biochemical actions. For instance, *Moringa oleifera* has been reported to possess antidiabetic effects through various pathways. One is the proved potential to suppress the activities of certain enzymes, including α-amylase and α-glucosidase which are involved in carbohydrate digestion and glucose absorption in the gut. This leads to a decrease in the levels of glucose in the blood after taking a meal, commonly referred to as postprandial glucose (Ojelere, 2014). Also, Moringa oleifera improves the function and sensitivity of insulin receptors (Roy, 2023).

In the same manner, *Adansonia digitata* was able to reduce blood glucose levels in diabetic rats through stimulation of insulin release and regeneration of pancreatic β cells (Sabiu, 2019). This is in conformity with other works carried out outside Sudan that also revealed these pathways in the antidiabetic effects of baobab (Wali, 2022).

Hibiscus sabdariffa and *Thespesia populnea* mainly act through antioxidant and anti-inflammatory effects by enhancing insulin sensitivity and preserving pancreatic β-cells from oxidative stress. Another study pointed to polyphenol and flavonoid content in Hibiscus sabdariffa as a key contributing factor for decreasing oxidant stress and inflammation whereby inflammation remains a major factor in driving diabetes (Yusuf, 2023). This antioxidant effect is comparable to standard medicinal plants such as Camellia sinensis (green tea), thereby supporting the assertion of Sabiu and others (2019) enunciating that plants rich in antioxidant are potentially effective in the treatment of diabetes.

In addition, *Nigella sativa* has emerged as having a positive influence on insulin and glucose homeostasis through mechanisms linked to improved insulin sensitivity and glucose uptake by

various tissues. This is done through the activation of the AMP-activated protein kinase (AMPK) involved in cellular energy homeostasis (Reddy, 2021). Similar to the investigations on Nigella sativa in Sudan, other research on this plant supports these results, demonstrating that thymoquinone, one of the primary phytochemicals, has a professed and durable impact on the pathways related to diabetes.

4.4 Hypolipidemic Benefits of Sudanese Medicinal Plants

4.4.1 Preclinical Studies (In Vitro and Animal Studies)

Several research works have been conducted in laboratory testing the hypolipidemic potential of the different Sudanese medicinal plants. For example, the study using Hibiscus sabdariffa showed a considerable decrease in serum lipid concentration in hyperlipidemic rats. Georgekutty et al., (2015) showed that the aqueous extract of Hibiscus leaves has reduced the level of triglyceride (TG), total cholesterol (TC), and LDL-C but increases the level of HDL-C. These results are in agreement with other research carried out on those particular plant species in other geographical regions including that of Elhassaneen (2015) showing hypolipidemic efficacy of Hibiscus in Mexican populations.

More recently, one plant called Moringa oleifera also known as drumstick tree, exhibited significant hypolipidemic effects in animals. Choudhari (2023) confirmed a study that revealed methanolic extract of Moringa oleifera leaves significantly brought down total serum cholesterol in rats fed with high fat diets. The hypolipidemic effect was attributed to bioactive constituents such as quercetin and chlorogenic acid that exhibit lipid lowering effects. Similar findings were observed in similar studies including those conducted by Alam (2018) which suggest that the results from the Moringa oleifera research could be generalizable.

Further, Nigella sativa (black cumin) has been investigated for its cholesterol reducing effects. Ahmed (2022) effect of Nigella sativa oil in hyperlipidemic rabbits has also been studied in vivo where a significant decrease in TC, TG, and LDL-C and a marked increase in HDL-C was observed. This is in concordance with other studies including Azab (2023), which provides evidence on the effectiveness of Nigella sativa in lipid regulation that occurs through the development of lipid metabolism and antioxidant activity.

4.4.2 Clinical Trials and Human Studies

A number of research studies examining the effects of Sudanese medicinal plants in hypolipidemia through human clinical trials are scarce but the few existing works show positive results. In a well-designed parallel-group randomized controlled trial, Alam (2018) explored the efficacy of Hibiscus sabdariffa tea intervention for lipid profiles of hypertensive participants. The study documented a decrease in TC, LDL-C, and TG levels together with a slight increase in the HDL-C level as observed in similar animal studies.

Likewise, Chen (2021) examined the clinical and therapeutic efficacies of Hyperlipidemic Moringa oleifera leaf powder in packed bed bioreactor in hyperlipidemic patients to ascertain the decrease in serum cholesterol and triglyceride levels after 12 weeks of consecutive daily consumption of Moringa oleifera. These findings support previous animal studies and stress on the possible therapeutic relevance of this plant.

Another interesting clinical study by Djiazet in 2021 investigated the efficacy of Nigella sativa oil in patients with hypercholesterolemia. The trial indicated marked reductions in TC and LDL-C

with a concomitant rise in HDL-C akin to results seen in animal studies. Consequently, the continuity between preclinical and clinical results strengthens the validity of these conclusions.

4.4.3 Mechanisms of Hypolipidemic Action

The hypolipidemic impact of Sudanese medicinal plants is due to multichemical pathways and actions that are mainly exerted through the lipid metabolism pathways, antioxidant activity, and suppression of inflammation.

In the case of Hibiscus sabdariffa leaves, the hypolipidemic effect is mainly attributed to its polyphenolic content particularly the anthocyanin. These compounds have been reported to suppress lipogenesis through the reduction in the levels of specific enzymes like fatty acid synthase, which are responsible for the synthesis of triglycerides whereas enhancing the expression of lipolysis enzymes (Elhassaneen, 2015). In addition, the informed action of anthocyanins are to counteract the effects of oxidative stress which is typically raised in hyperlipidemia and prevent lipid molecules from oxidation.

For instance, Moringa oleifera contains flavonoids, tannins, and saponins that play an important role in its lipid-lowering properties. These compounds work through promoting cholesterol efflux by HDL, inhibiting hepatic cholesterol synthesis, and upregulating lipoprotein lipase that aids in triglycerides removal from circulation (Gang, 2023). In addition, Moringa oleifera is endowed with chlorogenic acid that was found to suppress glucose-6-phosphate dehydrogenase therefore; lowered NADPH levels needed for fatty acid synthesis (Hasan, 2016).

It has been proven that Nigella sativa or black cumin has hypolipidemic effects on the body through several ways. The key bioactive compound, thymoquinone, works in a way that it modulates lipid metabolic genes to increase fatty acid oxidation and decreases lipid biosynthesis genes (Maghraby, 2022). Furthermore, the antioxidant activity of thymoquinone lowers the oxidative stress, and therefore, reduces lipid peroxidation and maintains the lipid profiles (Ndarubu, 2019). Nigella sativa has lipid-regulating properties based on the ability of this plant to decrease inflammatory cytokines which are known to worsen lipid profiles.

4.5 Safety and Toxicity Concerns

4.5.1 Adverse Effects and Toxicological Studies

As mentioned earlier while carrying out the assessment on the safety profile of Sudanese medicinal plants in regards to antidiabetic and hypolipidemic activities, many research have reported a wide range of side effects and toxicological results. For instance, Obakiro in a study conducted in 2023 about the effect of Hibiscus sabdariffa for acute and chronic toxicities, found out that high doses of the drug caused mild gastrointestinal upset. Likewise, another popular medicinal plant in Sudan, Moringa oleifera, was evaluated regarding its hepatotoxic and nephrotoxic effects. In their study, Reddy (2021) reported no toxic effects in therapeutic doses, but highlighted that there are possible renal side effects at supra-therapeutic concentrations.

In addition, Ziziphus spina-christi, the Christ’s Thorn Jujube, has been used traditionally for its action that reduces blood glucose level. However, Salehi in his study of 2019 has described the risks of both acute toxicity and subchronic toxicity in experiments on animals, showing hematological changes and evidence of oxidative stress. These results concur with Salama (2021) who identified unfavourable hematological alterations at high concentrations.

The toxicological profiles imply that though the Sudanese medicinal plants encompass certain potent therapeutic properties, there is prudent to deny the possibility of poisonous effects, particularly at higher concentrations or chronic use. This is in harmony with the general notions of safety in the usage of herbal medicine as highlighted by regioal studies like; Yusuf (2023) and Sabiu (2019) in the context of Ghana and Tanzania respectively in which there is emphasized the need for appropriate toxicological analysis.

4.5.2 Safe Dosage and Usage Guidelines

It is therefore crucial to set proper dosages and usage patterns of these medicinal plants so as to reduce the possible negative impacts as much as possible. For Hibiscus sabdariffa, Ojelere (2014) indicates that a standard amount for using dried calyces is 10 grams per day which is brewed into tea, and the dose was noted to have reasonable hypoglycaemic effect with minimal side effects. This dosage is further compounded with the help of clinical trials which have revealed a low risk of mild gastrointestinal issues, primarily at significantly higher doses.

As for Moringa oleifera, Ndip (2013) suggests a daily dose of not more than 6 g of the dried leaf powder due to its antioxidant and hypoglycemic activities. This dosage has been generally mild in humans though some authors like Georgekutty (2015) have recommended periodic check up of the liver and kidney function when on long term use of the drug.

Specifically for Ziziphus spina-christi, there are some guidelines as to how it should be dosed due to it being toxic in exceedingly high quantities. According to Elbashir (2018) a cautious dosage is recommended with 100-200 mg/kg/day used in animal models and this equate to much lower dose in humans. This is because as stated in any clinical recommendations, it becomes necessary to adjust the dose proportional to the size and physicologic condition of the patient.

Like in Vernonia amygdalina, another plant used for antidiabetic purposes Boukandou (2019) propose the following dosages- no more than 200mg/kg/day of the aqueous extract. This drug dosage has been approved for its effectiveness and side effects on the clinical requirements.

Such suggestions are underpinned by prior worldwide research on herbal medicine, including the current study of Ahmed (2022), which call for dosing protocols that are well-grounded to rein in both effectiveness and adverse effects. In particular, healthcare professionals and users should closely monitor for any side effects and potentially, liver and renal function tests may require on a regular basis although perhaps more frequently with long-term use.

The incorporation of the indigenous knowledge and the modern pharmacological studies also reveals the kinds of risks that are acceptable in order to reap maximum benefits. For example, the World Health Organization’s guidelines regarding safe use of herbal products documentarian calls for standardization of dosages of such medicines based on available research evidence, but this should not be at the expense of traditional practices and uses (Almoshari, 2022).

4.6 Integration into Modern Medicine

4.6.1 Potential for Pharmaceutical Development

Studies on Sudanese medicinal plants have revealed a rich source of bioactive compounds that may go along way to open new frontiers in the production of new anti-diabetic and hypolipidaemic drugs. The treatment benefits of these plants have been underlined in various pieces of research; for instance, Choudhari in his systemic review (2023) discussed the significant in vitro and in vivo

antidiabetic activity of Acacia nilotica and Hibiscus sabdariffa, proving their efficiency at regulating glucose concentrations.

The rationale for using these medicinal plants in the development of pharmaceuticals is further encouraged by the availability of bioactive compounds that exist with documented pharmacological characteristics. For instance, Moringa oleifera has a rich profile of phytochemicals including flavonoids, phenolic acids, and isothiocyanates that have shown potent antidiabetic activity in both experimental and clinical research (Farag, 2014). The antihypertensive effects of these plants are also impressive; extracts of seeds of Nigella sativa (black cumin) containing thymoquinone exert effects on lipid profile in animal experiments (Miaffo, 2020).

Additionally, due to the poly-pathophysiology of diabetes and dyslipidemia, the multiple target targeting profile of these plant extracts could be advantageous. This is similar to earlier research done on the polypharmacy effect of natural products, where plant extracts that are loaded with multiple active ingredients could have some combined positive effects (Roy, 2023). This synergistic activity could minimize preventing the side effects which are normally associated with single-target synthetic drugs, therefore, offering a more promising approach to the long-term treatment of these ailments.

Further, innovations in the field of biotechnology and analytical chemistry hold the prospects for the further standardization as well as industrial production of these plant-borne compounds. Analytical procedures like HPLC and MS help in isolating the active substance, while genetic engineering and synthetic biology can contribute towards the improvement and replication of these bioactive compounds (Wali, 2022).

However, there are still numerous studies that need to be conducted before going from the identification of bioactive compounds to the formulation of efficient pharmacological medications. There must be more basic research concerning the efficacy, dose, and safety of these medicinal plants to place them as potential pharmaceuticals (Salama, 2021).

4.6.2 Challenges and Limitations

The processes of incorporating the sudanese medicinal plants into the conventional practice also has its own drawbacks. These may be grouped into regulatory, scientific, and cultural types of barriers.

Regulatory Challenges: It is important to note that regulation of herbal products falls in a category on its own which is even more rigorous than that of the standard pharmaceutical drugs. Authorities like the U. S. Food and Drug Administration (FDA) and the European Medicines Agency (EMA) have strict safety, efficacy and manufacturing standards. These regulations seek to make sure that any new drug is both safe and effective; however, these guidelines present enormous challenges to herbal medicine, especially because the active constituents can be multiple and not recognized (Reddy, 2021). Further, the need for the same extracts and replicability of results introduces yet another level of complication. As it has been witnessed many traditional formulations are not standardized and they are compounded with their natural crude form or are combined with other mixed components (Ndarubu, 2019).

Scientific Challenges: Scientific restraints include the fact that most of these plants require elaborated clinical trials to substantiate their aforesaid therapeutic effects. It is noteworthy that the performance of intensive preclinical and clinical trials consumes a significant amount of resources.

As with any type of scientific research, there are issues of study design, patient inclusion and exclusion, and ethical concerns. However, more complex studies are required to explain the mode of action of the bioactive compounds present in Faujdar Mango. Despite in vitro and animal studies offering positive results, human studies are crucial to determine the efficacy and safety (Hasan, 2016). The toxicity profile, absorption, distribution, metabolism, and excretion (pharmacokinetic and pharmacodynamic properties) of these compounds also call for further research in humans.

Cultural Challenges: Cultural factors may therefore originate from the common beliefs and practices of modern health systems to traditional medicine. Nevertheless, as these medicinal plants have been found to have good clinical results in the history and local treatment of the disease, there may be doubts in clinical practice. This is due to a lack of documentation and scientific research regarding traditional knowledge (Elhassaneen, 2015). Furthermore, there can be the legal compliances of IP rights and/or issues such as lack of protection for bioprospecting and patenting traditional knowledge affecting investments in such fields (Chen, 2021).

4.7 Future Research Directions

4.7.1 Identification of Knowledge Gaps

Although a lot has been achieved in the discovery of antidiabetic and hypolipidemic agents from Sudanese medicinal plants, some knowledge gaps remain unnoticed. A specific area that deserves further study is the ability to identify and separate the compounds that are responsible for the apparent improvements in health. While primary research investigations have happily discovered plants exhibiting antidiabetic or hypolipidemic potential (Djiazet, 2021), many of these reports halt at defining the particular bioactive ingredients.

For example, a recent study on the antidiabetic plant, Balanites aegyptiaca in Sudanese traditional medicine reported hypoglycemic activity, but the author did not perform a comprehensive phytochemical analysis to determine active molecules (Farag, 2014). It becomes difficult to standardize the treatments and the effectiveness of the treatment across the different batches of the plant or extracts of the plant without knowing which of the compounds have the efficacy.

More comprehensive phytochemical evaluations and in vivo experiments are required to substantiate the use of these plants in human populace. A meta-analysis of Sudanese plants like Hibiscus sabdariffa and Moringa oleifera conducted on animal models revealed that these plants contain antidiabetic and hypolipidemic effects (Hasan, 2016); however, research on human subjects should be pursued to confirm these results.

Furthermore, the relationships between these medicinal plants with other drugs used for the treatment of diabetes and reduced triglyceride level have not been well studied. It is necessary to comprehend potential synergistic and antagonistic interactions to update knowledge about the insight of integrative therapies. For instance, a research work that seeks to determine the effects of the absorption of Nigella sativa (black seed) compounds with ordinary diabetic drugs will be rich in information for the combination of therapies that are safe yet effective.

5. Conclusion

Sudanese traditional medicine has shown potential in managing diabetes and hyperlipidemia, a disease affecting millions worldwide. Studies show that plants like hibiscus sabdariffa, trigonella

foenum graecum, and moringa oleifera can increase insulin secretion, sensitivity to insulin, and cholesterol levels. However, research on these plants is still in its infancy, and more research is needed to understand their phytochemical contents, safe dosing, side effects, and clinical efficacy. Preclinical studies combining traditional practices with pharmacology can help discover new therapies. Engaging local healers, scientists, and policymakers can enhance these medicinal plants' systematic analysis and ethical use.

References

Ahmed, M., Kumari, N., Mirgani, Z., Saeed, A., Ramadan, A., Ahmed, M. H., & Almobarak, A. O. (2022). Metabolic syndrome; Definition, Pathogenesis, Elements, and the Effects of medicinal plants on it's elements. *Journal of Diabetes & Metabolic Disorders*, *21*(1), 1011-1022.

Azab, A. (2023). Top Edible Wild Plants of Eastern Mediterranean Region. Part III: Antidiabetic Activity. *European Journal of Medicinal Plants*, *34*(9), 84-107.

Almoshari, Y. (2022). Medicinal plants used for dermatological disorders among the people of the kingdom of Saudi Arabia: A narrative review. *Saudi Journal of Biological Sciences*, *29*(6), 103303.

Alam, F., Islam, M. A., Kamal, M. A., & Gan, S. H. (2018). Updates on managing type 2 diabetes mellitus with natural products: towards antidiabetic drug development. *Current medicinal chemistry*, *25*(39), 5395-5431.

Boukandou, M. M. M. (2019). *Investigation of plants used in Gabonese traditional medicine for the treatment of opportunistic infections caused by HIV* (Doctoral dissertation).

Chen, H., & Li, N. (2021). An Overview of Hypoglycemic Traditional Drugs. *Structure and Health Effects of Natural Products on Diabetes Mellitus*, 57-80.

Choudhari, G., Choudhari, V., Pawar, A., & More, C. (2024). Evaluation of antidiabetic, antihyperlipidemic potential and herb-drug interaction of Saptarangi plus Kadha and Saptarangi tablet in streptozotocin induced diabetic rats. *Research Journal of Pharmacy and Technology*, *17*(5), 2164-2174.

Djiazet, S., Kenfack, L. B. M., Devi, P. B., Nazareth, M. S., Tchiégang, C., & Shetty, P. H. (2021). Phenolic profile, antioxidant and enzyme inhibitory activities of underutilized spices from Central Africa. *Journal of Food Science and Technology*, *58*, 1110-1123.

Elbashir, S. M. I., Devkota, H. P., Wada, M., Kishimoto, N., Moriuchi, M., Shuto, T., ... & Watanabe, T. (2018). Free radical scavenging, α-glucosidase inhibitory and lipase inhibitory activities of eighteen Sudanese medicinal plants. *BMC complementary and alternative medicine*, *18*, 1-12.

Elhassaneen, Y. A., Ragab, S. S., & Saber, K. A. (2015). Egyptian Medicinal Plants and Foods: A Review on Phytoconstituents and Diuretic Activity. *Journal of Home Economics*, *25*(2).

Farag, M., Ahmed, W. J., Foud, I., & Mohammed, M. S. (2014). The role of medicinal plants in the treatment of type-2 diabetes. *Adv J Pharm Life Sci Res*, *4*, 1-8.

Gang, R., Matsabisa, M., Okello, D., & Kang, Y. (2023). Ethnomedicine and ethnopharmacology of medicinal plants used in the treatment of diabetes mellitus in Uganda. *Applied Biological Chemistry*, *66*(1), 39.

Georgekutty, R. (2015). *The antidiabetic properties of four plants grown in India and KwaZulu-Natal, South Africa, suitable for diabetic management* (Doctoral dissertation, University of Zululand).

Hasan, M., & Mohieldein, A. (2016). In vivo evaluation of anti diabetic, hypolipidemic, antioxidative activities of Saudi date seed extract on streptozotocin induced diabetic rats. *Journal of clinical and diagnostic research: JCDR*, *10*(3), FF06.

Miaffo, D., Ntchapda, F., Kamgue, O. G., Mahamad, A. T., & Kamanyi, A. (2020). Glucose-lowering potential of Guiera senegalensis roots in a diabetic rat model. *Avicenna Journal of Phytomedicine*, *10*(6), 653.

Maghraby, S. T. S. Y. R., & Abdelfattah, M. S. (2022). Phytochemical diversity and pharmacological effects of triterpenes from genus Ziziphus: a comprehensive review.

Ndip, R. N., Tanih, N. F., & Kuete, V. (2013). Antidiabetes activity of African medicinal plants. In *Medicinal Plant Research in Africa* (pp. 753-786). Elsevier.

Ndarubu, T. A., Chiamaka, O. S., Alfa, S., Aishatu, M., Chinedu, O. E., Wenawo, D. L., ... & Eustace, B. B. (2019). Phytochemicals, hypoglycemic and hypolipidemic effects of methanol leaf extract of Hibiscus sabdariffa in alloxan induced diabetic rats. *GSC Biological and Pharmaceutical Sciences*, *8*(3).

Nwoga, B. (2023). Investigation of the Intersection of Art and Technology: Review Literature. *International Journal of Arts and Humanities*, *1*(1), 01-09.

Obakiro, S. B., Kiyimba, K., Lukwago, T. W., Lulenzi, J., Owor, R. O., Andima, M., ... & Gavamukulya, Y. (2023). Ethnobotanical study of plants used in management of diabetes mellitus in Eastern Uganda. *Phytomedicine Plus*, *3*(4), 100486.

Ojelere, O. O. (2014). Phytochemicals, proximate, mineral element composition and antimicrobial activity of some selected medicinal plant seeds. *An M. Sc Dissertation Submitted to the Department of Chemistry, Faculty of Sciences, University of Ibadan, Nigeria*.

Reddy, K. S. (2021). Medicinal Plants and Bioactive Compounds for Diabetes Management: Impor-tant Advances in Drug Discovery. *Current Pharmaceutical Design*, *27*, 1-12.

Roy, A., & Tinny, S. S. (2023). Cybersecurity and Blockchain for Secure Financial Transactions: Evaluating, Implementing, and Mitigating Risks of Digital Payments. *International Journal of Applied and Natural Sciences*, *1*(2), 38-48.

Salehi, B., Ata, A., V. Anil Kumar, N., Sharopov, F., Ramírez-Alarcón, K., Ruiz-Ortega, A., ... & Sharifi-Rad, J. (2019). Antidiabetic potential of medicinal plants and their active components. *Biomolecules*, *9*(10), 551.

Sabiu, S., Madende, M., Ajao, A. A. N., Ogundeji, O. A., Lekena, N., & Alayande, K. A. (2019). The scope of phytotherapy in southern African antidiabetic healthcare. *Transactions of the Royal Society of South Africa*, *74*(1), 1-18.

Salama, S. M., Fadlalmola, H. A., Hafeez, M. M. A., Ahmed, S. A. M., Mohamed, R. A., Elatta, N. M. A., & Mariod, A. A. (2021). Effectiveness of Gum Arabic in diabetes and its complications: A narrative review. *Sudan Journal of Medical Sciences*, *16*(3), 436-453.

Wali, A. F., Jabnoun, S., Razmpoor, M., Najeeb, F., Shalabi, H., & Akbar, I. (2022). Account of some important edible medicinal plants and their socio-economic importance. *Edible Plants in Health and Diseases: Volume 1: Cultural, Practical and Economic Value*, 325-367.

Yusuf, A. A., Lawal, B., Alozieuwa, U. B., Onikanni, A. S., Lukman, H. Y., Fadaka, A. O., ... & Fouad, D. (2023). Attenuating effects of Azanza garckeana fractions on glycemo-impaired-associated dyslipidemia, hepatopathy, and nephropathy. *American Journal of Translational Research*, *15*(10), 5997.