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Therapeutic Potential of *Moringa oleifera* Leaf Extract and *Nigella sativa* as Herbal Therapy in Diabetes Mellitus: A Literature Review

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ABSTRACT

Background: Diabetes mellitus (DM) is a metabolic disorder characterized by elevated blood glucose concentrations resulting from impaired insulin production, reduced insulin responsiveness, or a combination of both conditions. Increasing evidence indicates that oxidative imbalance and persistent inflammatory responses contribute substantially to the onset and progression of type 2 diabetes mellitus (T2DM). Consequently, medicinal plants with antioxidant and anti-inflammatory activities have gained attention as potential supportive interventions. **Objective:** This review aimed to evaluate published evidence regarding the antidiabetic properties of *Moringa oleifera* and *Nigella sativa*, particularly their influence on glucose metabolism, oxidative damage, and inflammatory pathways. **Methods:** A narrative review was performed using articles retrieved from PubMed, ScienceDirect, SpringerLink, Google Scholar, and accredited scientific journals. Publications from 2015–2024 were screened according to predefined eligibility criteria. Of 87 records initially identified, 17 studies were selected for analysis. **Results:** Available studies indicate that *Moringa oleifera* may assist glucose regulation through enzyme inhibition, improvement of insulin responsiveness, and enhancement of endogenous antioxidant defenses. Meanwhile, *Nigella sativa* and its principal bioactive constituent, thymoquinone, demonstrate glucose-lowering, antioxidant, and anti-inflammatory activities through modulation of oxidative stress and inflammatory mediators. Both plants have also shown protective effects against tissue damage associated with diabetes. **Conclusion:** Current findings support the potential role of *Moringa oleifera* and *Nigella sativa* as adjunctive approaches in diabetes management. Nevertheless, additional well-designed clinical investigations are required to establish their therapeutic effectiveness and long-term safety.
Keyword: diabetes mellitus, inflammation, *Moringa oleifera*, *Nigella sativa*, oxidative stress

ABSTRAK

Latar Belakang: Diabetes melitus (DM) merupakan gangguan metabolik kronis yang ditandai oleh peningkatan kadar glukosa darah akibat gangguan sekresi insulin, penurunan sensitivitas insulin, atau kombinasi keduanya. Selain hiperglikemia, stres oksidatif dan inflamasi kronis diketahui berkontribusi terhadap perkembangan serta progresivitas diabetes melitus tipe 2 (DMT2). Oleh karena itu, tanaman obat yang memiliki aktivitas antioksidan dan antiinflamasi semakin banyak diteliti sebagai terapi pendamping dalam pengelolaan diabetes. **Tujuan:** Tinjauan pustaka ini bertujuan mengevaluasi bukti ilmiah mengenai potensi antidiabetik *Moringa oleifera* dan *Nigella sativa*, khususnya terkait pengaruhnya terhadap metabolisme glukosa, stres oksidatif, dan jalur inflamasi. **Metode:** Penelitian dilakukan menggunakan metode *narrative literature review*. Artikel diperoleh dari basis data PubMed, ScienceDirect, SpringerLink, Google

Scholar, dan jurnal ilmiah terakreditasi. Publikasi tahun 2015–2024 diseleksi berdasarkan kriteria inklusi dan eksklusi yang telah ditetapkan. Dari 87 publikasi yang teridentifikasi, sebanyak 17 artikel memenuhi kriteria dan dianalisis. **Hasil:** Hasil kajian menunjukkan bahwa *Moringa oleifera* berpotensi membantu pengendalian glukosa melalui penghambatan enzim pencernaan karbohidrat, peningkatan sensitivitas insulin, serta penguatan sistem antioksidan endogen. Sementara itu, *Nigella sativa*, terutama melalui kandungan thymoquinone, menunjukkan aktivitas antihiperglikemik, antioksidan, dan antiinflamasi melalui modulasi stres oksidatif dan mediator inflamasi. Kedua tanaman juga berpotensi memberikan efek protektif terhadap kerusakan jaringan akibat diabetes. **Kesimpulan:** *Moringa oleifera* dan *Nigella sativa* memiliki potensi sebagai terapi komplementer pada diabetes melitus. Namun, penelitian klinis yang lebih terstandarisasi masih diperlukan untuk memastikan efektivitas dan keamanan penggunaannya dalam jangka panjang.
Keyword: diabetes melitus, inflamasi, *Moringa oleifera*, *Nigella sativa*, stres oksidatif

1. Introduction

Diabetes mellitus (DM) remains one of the most prevalent non-communicable diseases worldwide and continues to impose substantial clinical and economic burdens on healthcare systems. The condition is characterized by persistent elevation of blood glucose levels resulting from abnormalities in insulin secretion, insulin activity, or both mechanisms. The global incidence of diabetes has risen steadily over recent decades, driven by population aging, urbanization, obesity, physical inactivity, and unhealthy dietary patterns. [1,2]

Among the various forms of diabetes, type 2 diabetes mellitus (T2DM) represents the majority of reported cases. The disorder develops through a gradual decline in insulin responsiveness accompanied by deterioration of pancreatic β-cell function. Initially, β-cells attempt to compensate for insulin resistance by increasing insulin output; however, prolonged metabolic stress eventually compromises this adaptive response, resulting in sustained hyperglycemia. [2]

Recent investigations have highlighted the importance of oxidative stress and chronic inflammation in the pathophysiology of diabetes and its complications. Excess circulating glucose can stimulate excessive generation of *reactive oxygen species* (ROS) through several mechanisms, including mitochondrial dysfunction, protein kinase C activation, glucose autoxidation, and accumulation of advanced glycation end products. Elevated ROS levels may damage cellular macromolecules and disrupt normal insulin signaling pathways, thereby aggravating metabolic dysfunction. [3]

Inflammatory processes are also closely linked to diabetes progression. Persistent hyperglycemia promotes activation of intracellular signaling pathways such as *nuclear factor-kappa B* (NF-κB), leading to increased production of pro-inflammatory mediators including *tumor necrosis factor-alpha* (TNF-α), interleukin-1 beta (IL-1β), and interleukin-6 (IL-6). These mediators contribute to insulin resistance and may accelerate the development of diabetes-related complications. Consequently, diabetes is increasingly viewed as a disorder involving complex interactions between metabolic abnormalities, oxidative stress, and chronic inflammation. [3,4]

Management of T2DM generally combines lifestyle interventions with pharmacological treatment. Metformin remains the preferred first-line oral antidiabetic agent and has demonstrated benefits beyond glucose lowering, including modulation of oxidative stress, suppression of inflammatory activity, promotion of tissue repair, and protection against diabetic kidney injury. Despite these advantages, long-term disease control remains challenging, and complications may still occur in many patients. Such limitations have encouraged exploration of complementary strategies derived from medicinal plants and other natural products. [6–8]

Among the natural agents receiving considerable attention are *Moringa oleifera* and *Nigella sativa*. Both plants contain bioactive compounds that exhibit antioxidant, anti-inflammatory, and antihyperglycemic activities in experimental studies. Their potential ability to target multiple pathogenic mechanisms involved in diabetes has stimulated growing research interest. [9–17]

Moringa oleifera is rich in flavonoids, phenolic compounds, vitamins, chlorogenic acid, quercetin, and kaempferol. These phytochemicals have been associated with improved glucose utilization, reduced

oxidative injury, inhibition of digestive enzymes involved in carbohydrate breakdown, and enhanced insulin responsiveness. Experimental findings also suggest beneficial effects on metabolic homeostasis and protection against diabetes-related organ damage. [9–11]

Likewise, *Nigella sativa* has long been utilized in traditional medicine for various metabolic disorders. Its principal active constituent, thymoquinone, exhibits potent antioxidant and anti-inflammatory properties. Previous investigations have reported that thymoquinone may contribute to improved glycemic regulation, preservation of pancreatic β-cell integrity, reduction of oxidative injury, and suppression of inflammatory signaling pathways associated with diabetes progression. [12–17]

Given the increasing prevalence of diabetes and the expanding interest in scientifically validated herbal therapies, a comprehensive assessment of these medicinal plants is warranted. Therefore, this review was undertaken to examine current evidence concerning the antidiabetic effects of *Moringa oleifera* and *Nigella sativa*, with particular emphasis on their roles in glucose regulation, oxidative stress modulation, and inflammatory control. [9–17]

2. Method

This study employed a narrative review approach to evaluate scientific evidence regarding the antidiabetic activities of *Moringa oleifera* and *Nigella sativa*. Literature retrieval was conducted from January to May 2026 using several electronic databases, namely PubMed, ScienceDirect, SpringerLink, Google Scholar, and accredited national journals.

Search terms were combined using Boolean operators and included phrases such as “diabetes mellitus,” “type 2 diabetes,” “Moringa oleifera,” “Nigella sativa,” “thymoquinone,” “oxidative stress,” “inflammation,” and “herbal therapy.” Relevant combinations of these keywords were used to identify studies investigating the relationship between the selected medicinal plants and diabetes-related outcomes.

Only articles published between 2015 and 2024 were considered eligible. Included publications consisted of experimental studies, animal studies, clinical investigations, and review articles available in English or Indonesian. Studies were required to evaluate the effects of *Moringa oleifera* or *Nigella sativa* on glucose metabolism, insulin resistance, oxidative stress, inflammatory responses, or diabetic complications.

Publications were excluded when they represented duplicate records, conference abstracts lacking full manuscripts, studies unrelated to diabetes, reports with insufficient methodological information, or articles discussing traditional uses without scientific evaluation.

The selection process involved identification, screening, eligibility assessment, and final inclusion. A total of 87 publications were initially identified. After removal of duplicates and irrelevant studies, the remaining articles underwent full-text evaluation. Ultimately, 17 publications fulfilled the predetermined eligibility criteria and were included in the final synthesis.

Data extracted from each study included study design, experimental model, intervention characteristics, treatment duration, dosage, proposed mechanisms, and principal outcomes. The findings were subsequently organized and discussed according to thematic areas related to diabetes pathogenesis and potential herbal therapeutic mechanisms.

3. Discussion

3.1 The Role of Oxidative Stress and Inflammation in Diabetes Mellitus

The development of diabetes mellitus is influenced not only by disturbances in glucose metabolism but also by complex molecular processes involving oxidative damage and persistent inflammatory responses. Chronic elevation of blood glucose concentrations promotes excessive formation of *reactive oxygen species* (ROS), exceeding the capacity of endogenous antioxidant systems to maintain cellular balance. As a consequence, oxidative injury may occur in various tissues, including the pancreas, liver, kidneys, and vascular structures. [3]

Pancreatic β-cells are particularly vulnerable to oxidative damage because they possess relatively limited antioxidant defenses compared with other tissues. Excessive ROS accumulation can impair β-cell viability and reduce insulin secretory capacity, thereby contributing to deterioration of glycemic control. In addition,

oxidative stress may disrupt intracellular signaling pathways involved in insulin action, further aggravating insulin resistance. [3]

Besides oxidative injury, inflammatory mechanisms have been recognized as important contributors to diabetes progression. Hyperglycemia stimulates activation of several inflammatory signaling cascades, particularly the NF-κB pathway. Activation of this pathway enhances the expression of numerous pro-inflammatory mediators, including TNF-α, IL-1β, and IL-6, which are known to interfere with insulin signaling and metabolic regulation. [4]

The interaction between oxidative stress and inflammation creates a self-perpetuating cycle. Increased oxidative damage promotes inflammatory activation, while inflammatory mediators further stimulate ROS production. This reciprocal relationship contributes to progressive tissue injury and increases the risk of diabetic complications. Therefore, therapeutic agents capable of simultaneously targeting oxidative and inflammatory pathways may offer additional benefits beyond conventional glucose-lowering interventions. [3,4]

3.2 Antidiabetic Activities of Moringa oleifera

Research conducted during the past decade has identified *Moringa oleifera* as a promising medicinal plant with potential applications in diabetes management. Its leaves contain numerous phytochemical constituents, including polyphenols, flavonoids, chlorogenic acid, quercetin, and kaempferol, which have been associated with various biological activities relevant to metabolic health. [9–11]

Experimental studies consistently demonstrate that administration of *Moringa oleifera* extracts can reduce blood glucose concentrations in diabetic animal models. One proposed mechanism involves inhibition of digestive enzymes such as α-amylase and α-glucosidase. By slowing the breakdown and absorption of dietary carbohydrates, these effects may help reduce postprandial glucose excursions. [11]

Another important mechanism relates to antioxidant activity. Evidence indicates that *Moringa oleifera* enhances endogenous antioxidant defenses through increased activity of enzymes such as superoxide dismutase, catalase, and glutathione peroxidase. Strengthening these defense systems may reduce oxidative damage associated with chronic hyperglycemia and improve cellular function in metabolically active tissues. [9]

Studies have also suggested favorable effects on insulin responsiveness and hepatic glucose regulation. Through modulation of metabolic pathways involved in glucose utilization and production, *Moringa oleifera* may contribute to improved glycemic balance. In addition, several investigations have reported reductions in inflammatory markers following treatment, supporting its potential role in mitigating inflammation-related metabolic disturbances. [9,10]

Protective effects extending beyond glucose control have also been observed. Experimental findings indicate that *Moringa oleifera* may help preserve renal structure and function under diabetic conditions, suggesting a possible role in reducing the risk of diabetes-associated complications. [9]

3.3 Antidiabetic Activities of Nigella sativa

Nigella sativa has attracted considerable attention as a medicinal plant with broad pharmacological properties. Many of its biological effects are attributed to thymoquinone, a bioactive compound recognized for its antioxidant, anti-inflammatory, and cytoprotective activities. [12–17]

Multiple experimental studies have reported improvements in glycemic parameters following administration of *Nigella sativa* or thymoquinone. These improvements include reductions in fasting blood glucose levels, enhancement of insulin sensitivity, and attenuation of metabolic abnormalities associated with diabetes. The observed effects appear to involve several complementary mechanisms rather than a single biological pathway. [13–16]

A major therapeutic characteristic of thymoquinone is its ability to counteract oxidative stress. Investigations have demonstrated reductions in lipid peroxidation and free-radical-mediated damage together with enhancement of endogenous antioxidant systems. Such effects may help preserve pancreatic tissue integrity and support normal insulin production. [12–14]

The anti-inflammatory properties of thymoquinone also contribute to its potential antidiabetic activity. Evidence suggests that this compound can downregulate NF-κB activation and decrease the expression of inflammatory cytokines, including TNF-α, IL-1β, and IL-6. By limiting inflammatory signaling, *Nigella sativa* may reduce metabolic dysfunction associated with chronic inflammation. [12–14]

Additional studies have reported protective effects in organs commonly affected by diabetes, including the kidneys and skin. These findings suggest that *Nigella sativa* may provide broader benefits by attenuating tissue injury associated with prolonged hyperglycemia. [5,15,17]

3.4 Complementary Mechanisms of Moringa oleifera *and* Nigella sativa

Analysis of the available evidence indicates that *Moringa oleifera* and *Nigella sativa* influence different but interconnected aspects of diabetes pathophysiology. *Moringa oleifera* appears to exert stronger effects on carbohydrate metabolism, enzyme inhibition, insulin responsiveness, and antioxidant defense enhancement. In contrast, *Nigella sativa* demonstrates pronounced antioxidant, anti-inflammatory, and cytoprotective properties largely associated with thymoquinone activity. [9–17]

Because diabetes involves multiple pathogenic mechanisms simultaneously, agents acting through different pathways may theoretically provide complementary benefits. Combining interventions that improve glucose regulation while also reducing oxidative and inflammatory damage could potentially enhance overall metabolic outcomes. [3,4,9–17]

However, despite this theoretical rationale, direct evidence evaluating combined administration of *Moringa oleifera* and *Nigella sativa* remains scarce. No high-quality experimental or clinical studies specifically investigating their synergistic effects were identified during the literature search. Consequently, any proposed synergistic benefit remains speculative and requires validation through future research. [9–17]

3.5 Study Limitations and Future Directions

Several limitations should be considered when interpreting the findings summarized in this review. First, much of the available evidence originates from animal experiments and laboratory studies. Although these investigations provide valuable mechanistic insights, their findings cannot always be directly translated to clinical practice. [9–17]

Second, considerable variability exists among published studies regarding extraction procedures, plant preparations, administered doses, treatment duration, and outcome measurements. Such heterogeneity complicates comparison of results and limits the ability to establish standardized therapeutic recommendations. [9–17]

Third, information regarding long-term safety, herb-drug interactions, and optimal dosing regimens remains insufficient. These issues are particularly important because many patients with diabetes require prolonged treatment and often receive multiple medications simultaneously. [5–17]

Future investigations should prioritize well-designed randomized controlled trials involving larger patient populations. Standardization of herbal formulations, identification of active constituents, and comprehensive safety evaluations will be essential for determining the clinical applicability of *Moringa oleifera* and *Nigella sativa* as evidence-based complementary therapies for diabetes mellitus. [9–17]

4. Conclusion

Diabetes mellitus is a multifactorial metabolic disorder in which hyperglycemia, insulin resistance, oxidative imbalance, and chronic inflammation interact to drive disease progression and the development of complications. [2–4]

The evidence reviewed in this study indicates that *Moringa oleifera* and *Nigella sativa* possess biological activities that may support diabetes management through different yet complementary mechanisms. *Moringa oleifera* appears to contribute primarily through modulation of glucose metabolism, inhibition of carbohydrate-digesting enzymes, enhancement of antioxidant defenses, and improvement of insulin responsiveness. [9–11]

Conversely, *Nigella sativa*, particularly its major active constituent thymoquinone, demonstrates antioxidant, anti-inflammatory, antihyperglycemic, and tissue-protective effects that may help limit diabetes-related cellular damage and complications. [12–17]

Although the current findings are encouraging, most available evidence is derived from preclinical investigations. Additional randomized clinical trials employing standardized preparations and rigorous methodologies are required before these medicinal plants can be recommended as established components of diabetes management. [9–17]

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