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Unlocking the Insightful Antidiabetic Effects of Lemongrass (*Cymbopogon citratus*): A Compact Review

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ABSTRACT: Lemongrass (*Cymbopogon citratus*) has emerged as a noteworthy contender in traditional medicine for its aromatic and therapeutic attributes, yet its potential as an antidiabetic agent remains largely unexplored in the literature. To address this gap, this study endeavors to provide a comprehensive overview of lemongrass role in diabetes management and the underlying pathways involved. Rich in bioactive compounds such as citral, flavonoids, and essential oils, lemongrass boasts a diverse array of medicinal properties. Research indicates its capability to modulate blood glucose levels, improve insulin sensitivity, and fortify pancreatic β-cell function primarily through antioxidant and anti-inflammatory mechanisms. Animal studies have demonstrated substantial reductions in fasting blood glucose and enhanced glucose tolerance, ascribed to heightened insulin signaling and inhibition of carbohydrate metabolism enzymes. Additionally, lemongrass exhibits a positive impact on lipid profiles, thereby mitigating cardiovascular risks associated with diabetes. Limited human trials have corroborated these findings, showcasing improvements in glycemic control and lipid metabolism following lemongrass consumption. In conclusion, lemongrass emerges as a promising adjunctive therapy for diabetes management, owing to its natural composition and multifaceted mechanisms. Nonetheless, further investigation, particularly through rigorous clinical trials, is imperative to determine optimal dosages, long-term safety, and efficacy, thereby facilitating its seamless integration into conventional diabetes treatment protocols.

Keywords: Lemongrass; *Cymbopogon citratus*; diabetes; antidiabetic effects; oxidative stress; glycemic control.

1. Introduction

Diabetes mellitus is a chronic metabolic disorder characterized by persistent hyperglycemia due to insufficient insulin production, impaired insulin action, or both (Khan, 2022; Khan et al., 2020). The prevalence of diabetes is rising globally, posing significant health challenges due to its associated complications, including cardiovascular disease, neuropathy, nephropathy, and retinopathy. Effective management of diabetes typically involves lifestyle modifications, pharmacological interventions, and, increasingly, the exploration of natural remedies with potential antidiabetic properties (Association, 2020). Among such natural remedies, lemongrass (*Cymbopogon citratus*) has garnered attention for its potential to improve diabetes resistance and manage hyperglycemia (Garba et al., 2020; Villalobos et al., 2021; Widiputri et al., 2018). potential to improve diabetes resistance and manage hyperglycemia (American Diabetes Association. 2020). Lemongrass, a perennial plant native to tropical regions, is extensively used in culinary and traditional medicinal practices. It is valued for its aromatic properties and diverse therapeutic benefits, including its antimicrobial, anti-inflammatory, antioxidant, and antidiabetic effects. The primary bioactive constituents of lemon grass include citral, flavonoids, phenolic compounds, and essential oils, which collectively contribute to its health-promoting properties. Recent studies have focused on understanding the antidiabetic mechanisms of lemon grass, exploring its role in enhancing insulin sensitivity, modulating blood glucose levels, and protecting pancreatic β-cells (Bailey, C. J., & Day, C. 1989). One of the critical mechanisms through which lemon grass exerts its antidiabetic effects is its antioxidant activity. Oxidative stress is a well-recognized factor in the pathogenesis of diabetes, contributing to insulin resistance and β-cell dysfunction. Lemon grass is rich in antioxidants that scavenge free radicals, thereby reducing oxidative damage and improving cellular function. This reduction in oxidative stress is crucial for maintaining the integrity and function of insulin-producing β-cells in the pancreas (Bhatia, P. *et.al.*,2016).

In addition to its antioxidant properties, lemongrass exhibits significant anti-inflammatory effects. Chronic inflammation is closely linked to the development of insulin resistance and type 2 diabetes. Inflammatory cytokines such as TNF-α and IL-6 interfere with insulin signaling pathways, leading to impaired glucose uptake and increased blood glucose levels. Compounds in lemon grass, particularly flavonoids and phenolic acids, have been shown to inhibit the production of pro-inflammatory cytokines, thereby ameliorating inflammation and enhancing insulin sensitivity (Bhatia, P. *et.al.*,2016). Lemon grass also directly influences carbohydrate metabolism. Studies indicate that lemon grass extracts can inhibit key enzymes involved in carbohydrate digestion and glucose absorption, such as α-amylase and α-glucosidase. By inhibiting these enzymes, lemongrass slows down the breakdown of carbohydrates into glucose, resulting in a more gradual increase in blood sugar levels post-meal. This enzymatic inhibition is particularly beneficial for managing postprandial hyperglycemia, a common challenge in diabetic patients.

Animal studies provide compelling evidence for the antidiabetic effects of lemon grass. Research involving diabetic rodent models has demonstrated that lemon grass extracts can significantly lower fasting blood glucose levels, improve glucose tolerance, and enhance lipid profiles. These effects are attributed to the activation of insulin signaling pathways, increased glucose uptake in peripheral tissues, and improved pancreatic function. Moreover, the lipid-lowering effects of lemon grass contribute to better cardiovascular health, which is crucial given the heightened risk of cardiovascular diseases in diabetic individuals (Chagas, P. M. B. *et al.*,2020). Human studies, though limited, support the potential benefits of lemon grass in diabetes management. Preliminary clinical trials have reported improvements in glycemic control and lipid metabolism in diabetic patients consuming lemon grass tea or supplements. These findings suggest that lemon grass could be a valuable adjunct therapy in managing diabetes,

complementing conventional treatments and lifestyle interventions.

Despite the promising evidence, further research is needed to fully elucidate the antidiabetic mechanisms of lemon grass and establish its efficacy and safety in long-term use. Large-scale clinical trials are essential to determine the optimal dosages and formulations for therapeutic use. Additionally, understanding the interactions of lemon grass with conventional antidiabetic medications will be crucial for its integration into standard treatment protocols (Choi, J. H. *et al.*, 2019). Lemon grass presents a promising natural remedy for enhancing diabetes resistance and managing hyperglycemia. Its multifaceted mechanisms, including antioxidant, anti-inflammatory, and enzymatic inhibition properties, underscore its potential as a complementary therapy in diabetes care. As research progresses, lemon grass may become a valuable component of holistic diabetes management strategies, offering a natural and accessible option for improving health outcomes in diabetic patients.

2. Lemongrass: Botanical and Biological Profile

Lemongrass, known scientifically as *Cymbopogon citratus*, is a tropical perennial plant belonging to the Poaceae family (Kamaruddin et al., 2022; Majewska et al., 2019; Oladeji et al., 2019). It is characterized by long, slender leaves and a strong lemon scent, which is due to its high content of essential oils. Lemongrass, a perennial plant native to tropical regions, is extensively used in culinary and traditional medicinal practices (Lawal et al., 2017; Mirghani et al., 2012; Oladeji et al., 2019). It is valued for its aromatic properties and diverse therapeutic benefits, including its antimicrobial, anti-inflammatory, antioxidant, and antidiabetic effects. The primary bioactive constituents of lemongrass include citral, flavonoids, phenolic compounds, and essential oils, which collectively contribute to its health-promoting properties. Recent studies have focused on understanding the antidiabetic mechanisms of lemongrass, exploring its role in enhancing insulin sensitivity, modulating blood glucose levels, and protecting pancreatic β-cells (Adeneye and Agbaje, 2007; Bailey and Day, 1989).

One of the critical mechanisms through which lemongrass exerts its antidiabetic effects is its antioxidant activity. Oxidative stress is a well-recognized factor in the pathogenesis of diabetes, contributing to insulin resistance and β-cell dysfunction. Lemongrass is rich in antioxidants that scavenge free radicals, thereby reducing oxidative damage and improving cellular function. This reduction in oxidative stress is crucial for maintaining the integrity and function of insulin-producing β-cells in the pancreas (Sari et al., 2017; Widiputri et al., 2018).

In addition to its antioxidant properties, lemongrass exhibits significant anti-inflammatory effects. Chronic inflammation is closely linked to the development of insulin resistance and type 2 diabetes. Inflammatory cytokines such as TNF-α and IL-6 interfere with insulin signaling pathways, leading to impaired glucose uptake and increased blood glucose levels. Compounds in Lemongrass, particularly flavonoids and phenolic acids, have been shown to inhibit the production of pro-inflammatory cytokines, thereby ameliorating inflammation and enhancing insulin sensitivity (Garba et al., 2020; Sari et al., 2017; Villalobos et al., 2021).

Lemongrass also directly influences carbohydrate metabolism. Studies indicate that lemongrass extracts can inhibit key enzymes involved in carbohydrate digestion and glucose absorption, such as α-amylase and α-glucosidase. By inhibiting these enzymes, lemongrass slows down the breakdown of carbohydrates into glucose, resulting in a more gradual increase in blood sugar levels post-meal. This enzymatic inhibition is particularly beneficial for managing postprandial hyperglycemia, a common challenge in diabetic patients (Santoso et al., 2018).

Animal studies provide compelling evidence for the antidiabetic effects of Lemongrass. Research involving diabetic rodent models has demonstrated that Lemongrass extracts can significantly lower fasting blood glucose levels, improve glucose tolerance, and enhance lipid profiles. These effects are attributed to the activation of insulin signaling pathways, increased glucose uptake in peripheral tissues,

and improved pancreatic function. Moreover, the lipid-lowering effects of lemongrass contribute to better cardiovascular health, which is crucial given the heightened risk of cardiovascular diseases in diabetic individuals (Kumar et al., 2011; Somparn et al., 2018).

Human studies, though limited, support the potential benefits of Lemongrass in diabetes management. Preliminary clinical trials have reported improvements in glycemic control and lipid metabolism in diabetic patients consuming Lemongrass tea or supplements. These findings suggest that Lemongrass could be a valuable adjunct therapy in managing diabetes, complementing conventional treatments and lifestyle interventions. Despite the promising evidence, further research is needed to fully elucidate the antidiabetic mechanisms of Lemongrass and establish its efficacy and safety in long-term use. Large-scale clinical trials are essential to determine the optimal dosages and formulations for therapeutic use. Additionally, understanding the interactions of Lemongrass with conventional antidiabetic medications will be crucial for its integration into standard treatment protocols (Garba et al., 2020).

3. Chemistry of Lemongrass

Lemongrass (*Cymbopogon citratus*) is a perennial herb renowned for its aromatic qualities and a wide range of medicinal properties (Nambiar and Matela, 2012; Ullah et al., 2020; Wifek et al., 2016). The therapeutic potential of Lemongrass is attributed to its rich phytochemical composition, which includes essential oils, flavonoids, phenolic compounds, and other bioactive constituents. These compounds collectively contribute to the plant's antimicrobial, anti-inflammatory, antioxidant, and antidiabetic effects. Understanding the chemistry of Lemongrass is essential for elucidating the mechanisms through which it exerts its antidiabetic properties (Ganjewala and Gupta, 2013; Gupta and Sharma, 2017; Jugreet et al., 2020).

3.1. Essential Oils

The most prominent component of Lemongrass is its essential oil, which constitutes about 0.2-0.4% of the plant's fresh weight. The essential oil is predominantly composed of citral, a mixture of two geometric isomers: neral (citral a) and geranial (citral b). Citral accounts for approximately 70-80% of the essential oil and is responsible for the characteristic lemon aroma of the herb. Citral is known for its potent antimicrobial and anti-inflammatory properties. Additionally, it exhibits antioxidant activity by scavenging free radicals and reducing oxidative stress, which is crucial in managing diabetes (Hanaa et al., 2012; Majewska et al., 2019; Mirghani et al., 2012).

3.2. Flavonoids

Lemongrass contains a variety of flavonoids, such as quercetin, kaempferol, and luteolin. Flavonoids are polyphenolic compounds that have been extensively studied for their health benefits. They exhibit strong antioxidant properties, protecting cells from oxidative damage by neutralizing reactive oxygen species (ROS) (Gaba et al., 2020; Miean and Mohamed, 2001; Tazi et al., 2024). Flavonoids also possess anti-inflammatory properties, which can help mitigate chronic inflammation associated with insulin resistance and type 2 diabetes. By inhibiting the production of pro-inflammatory cytokines like TNF-α and IL-6, flavonoids enhance insulin sensitivity and glucose uptake in cells (Gaba et al., 2020; Khan et al., 2023).

3.3. Phenolic Compounds

Phenolic compounds in Lemongrass, including caffeic acid, chlorogenic acid, and ferulic acid, contribute significantly to its medicinal properties. These compounds are known for their antioxidant activity, which plays a vital role in protecting pancreatic β-cells from oxidative stress-induced damage. Oxidative stress is a key factor in the development and progression of diabetes, and phenolic compounds help maintain the functional integrity of β-cells, thereby supporting insulin production and secretion, figure 1 comprehensively summarizes the major chemical constituents of the lemongrass (Costa et al., 2016; Jaganath, 2000; Muala et al., 2021; Nambiar and Matela, 2012).

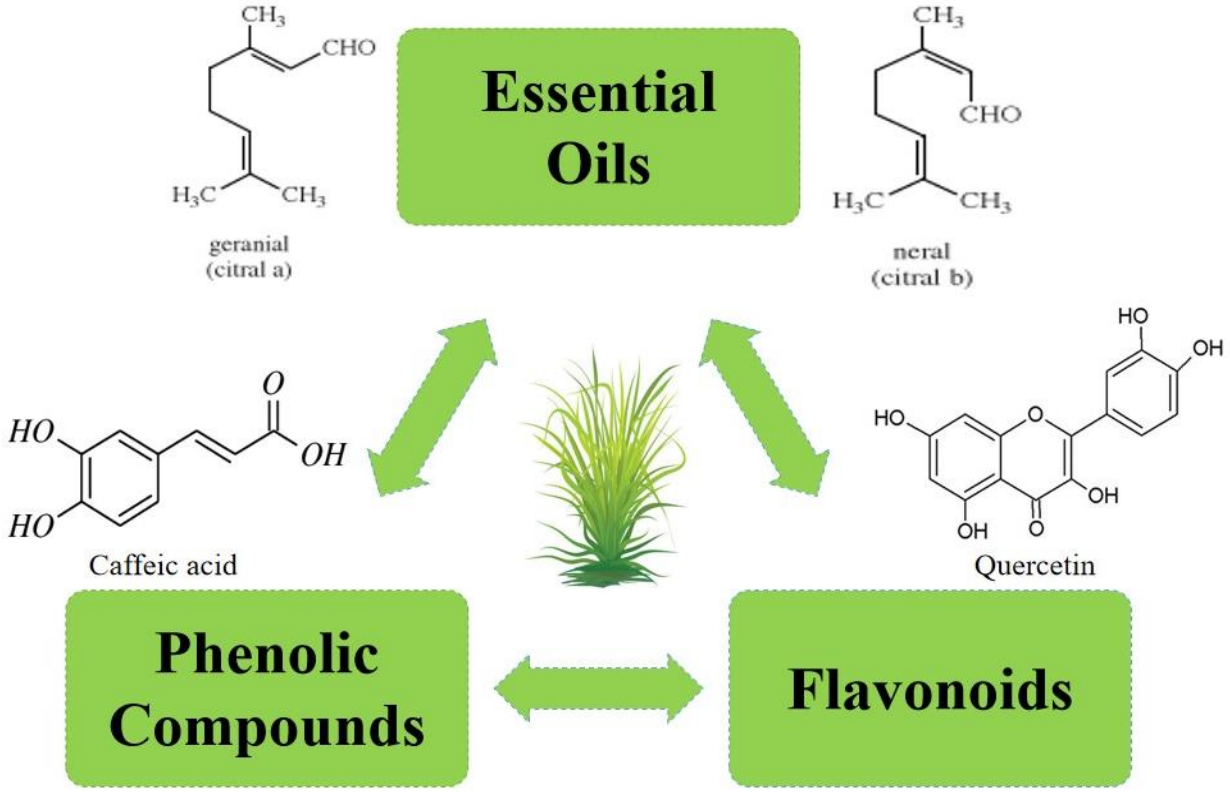

Fig. 1: Chemical structures of the major constituents of Lemongrass.

4. Pharmacology Potential of Lemongrass

Lemongrass (*Cymbopogon citratus*) is a perennial herb widely used in culinary and traditional medicinal practices, renowned for its distinctive lemon aroma and a broad spectrum of therapeutic properties. Its medicinal potential is primarily attributed to its rich phytochemical composition, including essential oils, flavonoids, phenolic compounds, and other bioactive constituents. This review explores the therapeutic potential of Lemongrass, emphasizing its antimicrobial, anti-inflammatory, antioxidant, and antidiabetic effects (Boukhatem et al., 2014; Ewenighi et al., 2013; Nambiar and Matela, 2012; Ullah et al., 2020).

4.1. Antimicrobial Properties

Lemongrass exhibits significant antimicrobial activity, primarily due to its high content of essential oils, particularly citral (a combination of neral and geranial). Citral is known for its potent antibacterial and antifungal properties, making Lemongrass effective against a wide range of pathogens (Silva et al., 2008; Tzortzakis and Economakis, 2007; Valková et al., 2022). Studies have demonstrated that Lemongrass essential oil can inhibit the growth of bacteria such as *Staphylococcus aureus*, *Escherichia coli*, and *Salmonella spp*., as well as fungi including *Candida albicans*. These antimicrobial properties support the use of Lemongrass in treating infections and preserving food, such potential is worth noted in case infections in diabetics. (Silva et al., 2008; Tzortzakis and Economakis, 2007).

4.2. Anti-Inflammatory Effects

Chronic inflammation is implicated in various diseases, including arthritis, cardiovascular diseases, and diabetes. Lemongrass contains several anti-inflammatory compounds, such as flavonoids and phenolic acids, which help reduce inflammation by inhibiting the production of pro-inflammatory cytokines like TNF-α and IL-6. By modulating the inflammatory response, Lemongrass can alleviate symptoms of inflammatory conditions and improve overall health. This anti-inflammatory activity also contributes to its

antidiabetic effects, as chronic inflammation is a key factor in the development of insulin resistance (Boukhatem et al., 2014; Figueirinha et al., 2010).

4.3. Antioxidant Activity

Oxidative stress, caused by an imbalance between free radicals and antioxidants in the body, is a major contributor to aging and various chronic diseases, including cancer, cardiovascular diseases, and diabetes (Balakrishnan et al., 2014; Cheel et al., 2005; Khan et al., 2023). Lemongrass is rich in antioxidants, including citral, flavonoids, and phenolic compounds, which scavenge free radicals and protect cells from oxidative damage. This antioxidant activity is crucial for maintaining cellular health and preventing the oxidative stress-related damage that can lead to chronic diseases (Cheel et al., 2005).

4.4. Antidiabetic Action

4.4.1. Antioxidant Activity

One of the primary mechanisms by which Lemongrass exerts its antidiabetic effects is through its potent antioxidant activity. Oxidative stress, characterized by an overproduction of reactive oxygen species (ROS) (Wang, Y. et al., 2022), is a major factor in the pathogenesis of diabetes, leading to β-cell dysfunction and insulin resistance. The antioxidants in Lemongrass, particularly flavonoids and phenolic acids, scavenge free radicals, reducing oxidative damage and preserving the function of pancreatic β-cells, as illustrated in Figure 2. This protection is crucial for maintaining adequate insulin production and secretion (Esmaeili et al., 2009).

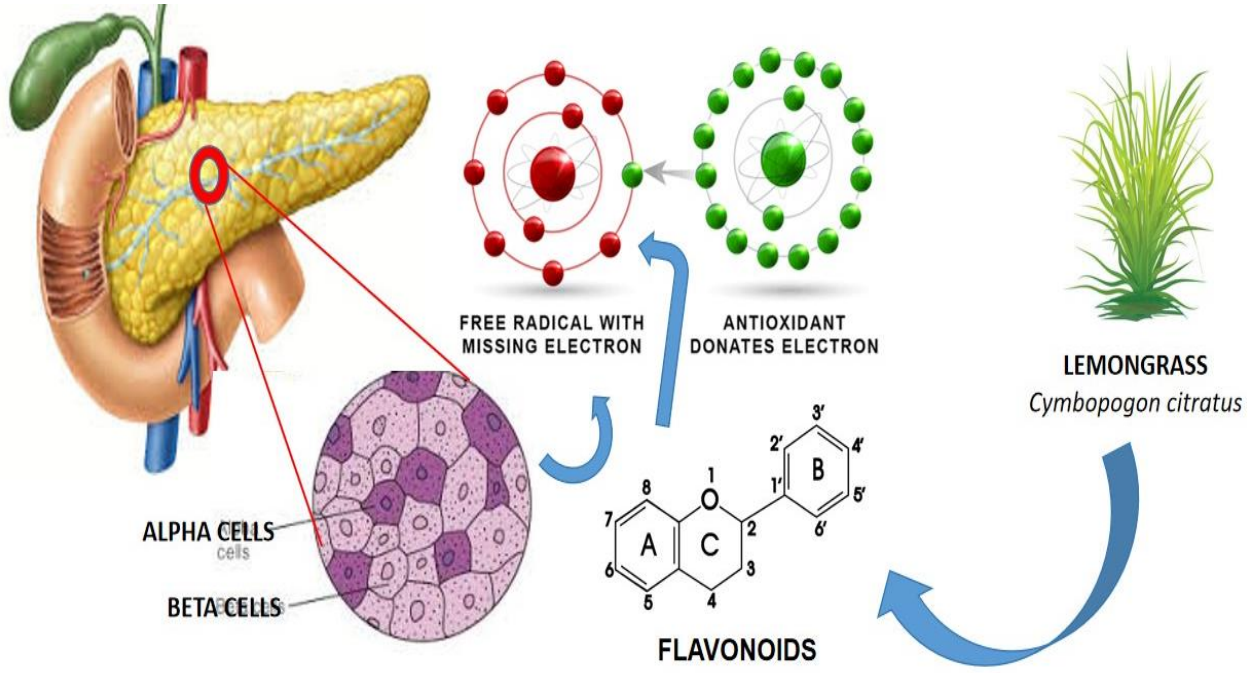

Fig. 2: Illustrates the antioxidant mechanism of flavonoids obtained from lemongrass scavenging free radicals.

4.4.2. Anti-Inflammatory Effects

Chronic inflammation is closely linked to the development of insulin resistance and type 2 diabetes. Pro-inflammatory cytokines like TNF-α and IL-6 can interfere with insulin signaling pathways, exacerbating hyperglycemia. Compounds in Lemongrass, especially citral and flavonoids, exhibit significant anti-inflammatory properties. They inhibit the production of these cytokines, thereby reducing inflammation and improving insulin sensitivity (Ekpenyong et al., 2015; Elekofehinti et al., 2020).

4.4.3. Enzymatic Inhibition

Lemongrass has been shown to inhibit key enzymes involved in carbohydrate metabolism, such as α-amylase and α-glucosidase (Borges et al., 2021). These enzymes are responsible for breaking down carbohydrates into glucose, which is then absorbed into the bloodstream. By inhibiting these enzymes, Lemongrass slows the digestion and absorption of carbohydrates, leading to a more gradual increase in blood glucose levels post-meal. This enzymatic inhibition is particularly beneficial for managing postprandial hyperglycemia, a common challenge in diabetic patients, as reflected in Figure 3 (Borges et al., 2021; Peter et al., 2021).

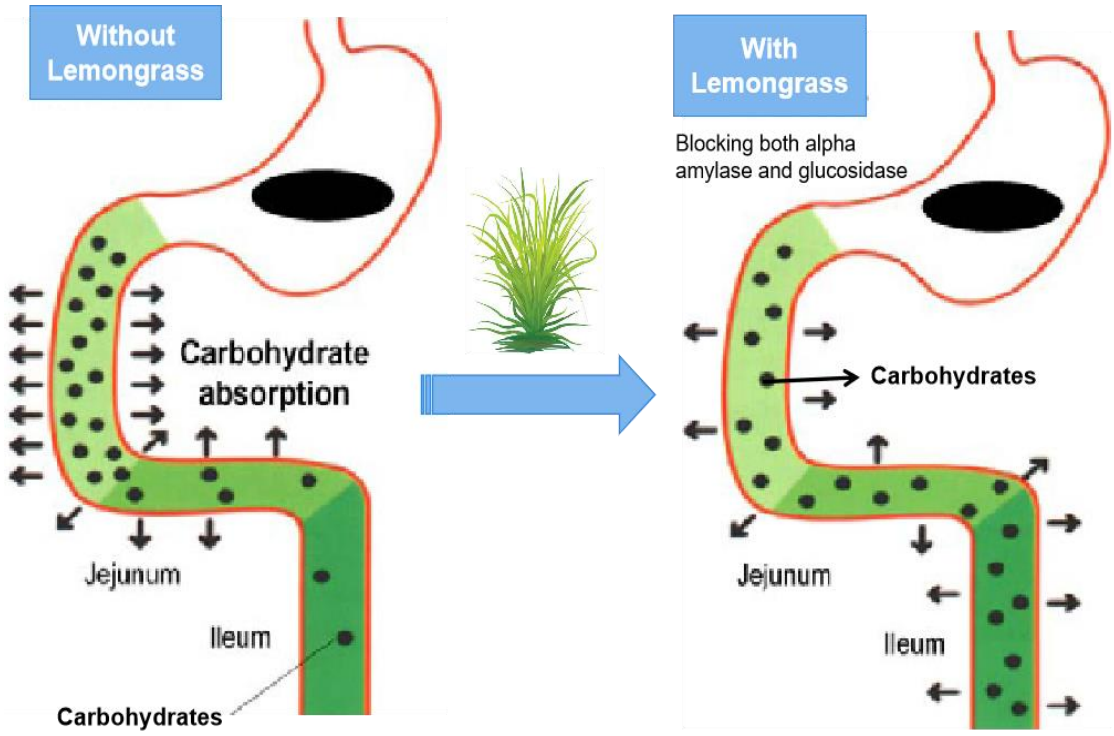

Fig. 3: The antidiabetic activity of lemongrass based on blocking alpha amylase and glucosidase enzymes.

4.4.4. Lipid Profile Improvement

Improving lipid profiles is another mechanism through which Lemongrass exerts its antidiabetic effects. Diabetes is often associated with dyslipidemia, characterized by elevated levels of total cholesterol, low-density lipoprotein (LDL), and triglycerides, and reduced levels of high-density lipoprotein (HDL). Lemongrass has been found to lower total cholesterol, LDL, and triglycerides while increasing HDL levels. These lipid-modulating effects reduce the risk of cardiovascular complications, which are prevalent among diabetic individuals (Kiełtyka-Dadasiewicz et al., 2021; Somparn et al., 2018). The antidiabetic effects of lemongrass based on four cardinal contributing factors, as depicted in Figure 4.

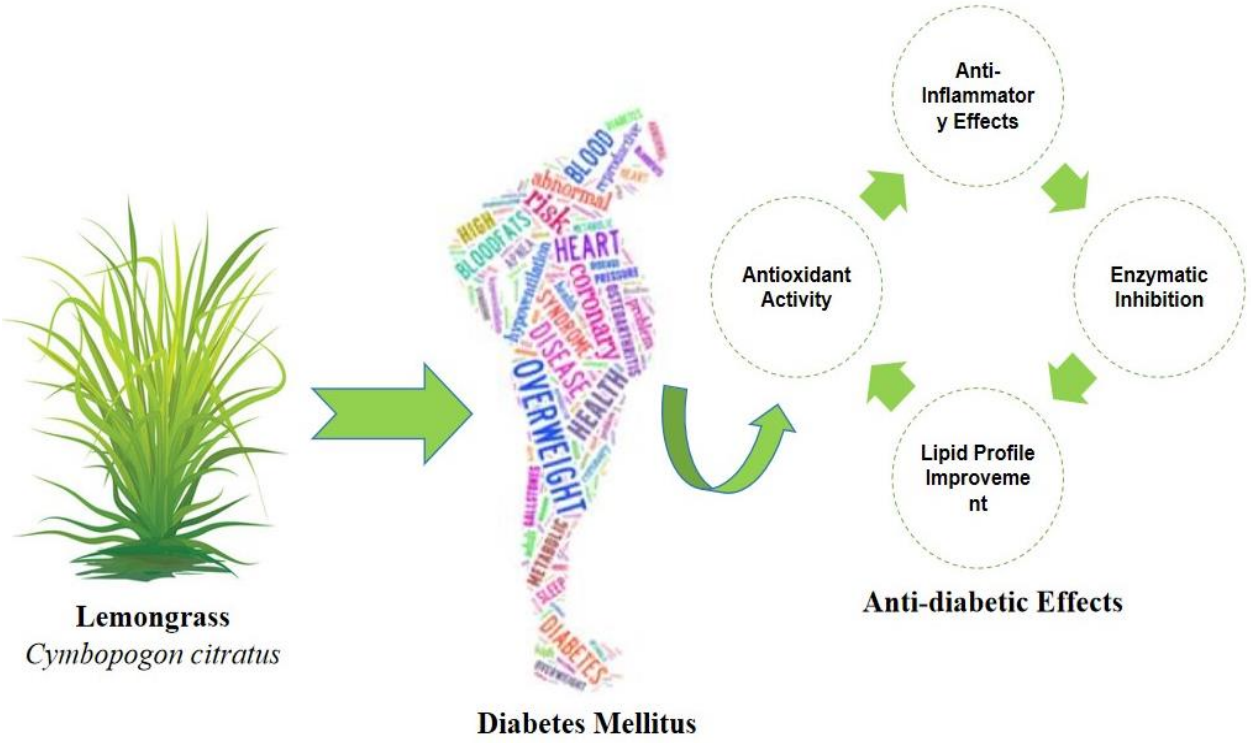

Fig. 4: Antidiabetic Effects of Lemongrass.

4.4.5. Evidence Studies

Animal studies have provided compelling evidence for the antidiabetic effects of Lemongrass. Research involving diabetic rodent models has shown that lemongrass extracts can significantly lower fasting blood glucose levels, improve glucose tolerance, and enhance lipid profiles. These effects are attributed to the activation of insulin signaling pathways, increased glucose uptake in peripheral tissues, and improved pancreatic function (Ademuyiwa et al., 2015).

Human studies, although limited, also suggest potential benefits. Preliminary clinical trials have reported improvements in glycemic control and lipid metabolism in diabetic patients consuming Lemongrass tea or supplements. These findings indicate that Lemongrass could be a valuable adjunct therapy in diabetes management, complementing conventional treatments and lifestyle interventions (Garba et al., 2020).

Lemongrass demonstrates significant potential as a natural remedy for managing diabetes (El-Sayed et al., 2013; Garba et al., 2020). Its multifaceted antidiabetic mechanisms, including antioxidant, anti-inflammatory, and enzymatic inhibition properties, make it a promising candidate for complementary diabetes therapy (Puteri et al., 2020). Further research, particularly large-scale clinical trials, is needed to fully establish its efficacy, optimal dosages, and long-term safety. As research progresses, Lemongrass may become an integral part of holistic diabetes management strategies, offering a natural and accessible option for improving health outcomes in diabetic patients (Gaba et al., 2020; Leite et al., 1986).

4.5. Insulin resistance: Current Treatment Approaches

Current treatment strategies for diabetes include lifestyle modifications, pharmacotherapy, and in some cases, insulin therapy. Commonly used antidiabetic drugs include metformin, sulfonylureas, thiazolidinediones, and DPP-4 inhibitors (Khan et al., 2020; Pappachan et al., 2019). Despite the availability of these medications, achieving optimal glycemic control remains challenging for many patients, necessitating the exploration of complementary and alternative therapies.

Natural remedies, including medicinal plants, have gained attention for their potential to manage diabetes and its complications. Lemongrass (*Cymbopogon citratus*) is one such plant that has been traditionally used for its

various medicinal properties (Avoseh et al., 2015; Suroowan and Mahomoodally, 2016). This review aims to comprehensively examine the antidiabetic potential of Lemongrass, focusing on its mechanisms of action, preclinical and clinical evidence, and its role in enhancing diabetes resistance.

4.5.1. Antioxidant Activity

Oxidative stress plays a significant role in the pathogenesis of diabetes by damaging pancreatic β-cells and impairing insulin function. The antioxidants in Lemongrass, particularly flavonoids and phenolic acids, help scavenge reactive oxygen species (ROS) and reduce oxidative damage, thus preserving β-cell function and improving insulin sensitivity (Esmaeili et al., 2009; Wang, H. et al., 2022).

4.5.2. Anti-Inflammatory Effects

Chronic inflammation is closely linked to the development of insulin resistance. Lemongrass contains anti-inflammatory compounds that inhibit pro-inflammatory cytokines such as TNF-α and IL-6, thereby reducing inflammation and enhancing insulin signaling pathways (Ekpenyong et al., 2015).

4.5.3. Enzymatic Inhibition

Lemongrass has been shown to inhibit carbohydrate-digesting enzymes such as α-amylase and α-glucosidase. This inhibition slows down the breakdown of carbohydrates into glucose, resulting in a more gradual increase in blood glucose levels post-meal, which is beneficial for managing postprandial hyperglycemia (Borges et al., 2021).

4.5.4. Lipid Profile Improvement

Improvement in lipid profiles is another way Lemongrass exerts its antidiabetic effects. It lowers levels of total cholesterol, LDL, and triglycerides while increasing HDL levels, thus reducing the risk of cardiovascular complications associated with diabetes (Wang, H. et al., 2022).

4.5.5. Insulin Sensitivity Enhancement

Bioactive compounds in Lemongrass, particularly citral, enhance insulin sensitivity by improving insulin receptor function and glucose uptake in peripheral tissues. This effect helps maintain better glycemic control (Garba et al., 2020).

4.6. Preclinical and Clinical Studies on Lemongrass and Diabetes

Preclinical studies involving diabetic rodent models have shown that Lemongrass extracts can significantly lower fasting blood glucose levels, improve glucose tolerance, and enhance lipid profiles. These studies highlight the potential mechanisms by which Lemongrass exerts its antidiabetic effects (Adeneye and Agbaje, 2007; El-Sayed et al., 2013). In vitro studies have demonstrated the ability of Lemongrass extracts to inhibit key enzymes involved in glucose metabolism and reduce oxidative stress in pancreatic β-cells. These findings support the potential of Lemongrass as a therapeutic agent for diabetes (Puteri et al., 2020; Wang, H. et al., 2022).

4.6.1. Clinical Evidence for Lemongrass in Diabetes Management

Although limited, human trials have provided preliminary evidence supporting the antidiabetic effects of Lemongrass. These studies have reported improvements in glycemic control and lipid metabolism in diabetic patients consuming Lemongrass tea or supplements. Lemongrass has been generally recognized as safe for consumption, with few reported side effects. However, more extensive clinical trials are needed to establish its long-term safety and efficacy in diabetes management. Optimal dosages and administration methods for therapeutic use of Lemongrass are yet to be determined. Current studies have used various forms, including teas, extracts, and supplements, highlighting the need for standardized formulations (Garba et al., 2020).

4.7. Comparative Analysis: Lemongrass and Conventional Antidiabetic Drugs

4.7.1. Mechanistic Comparisons

Comparing the mechanisms of Lemongrass with conventional antidiabetic drugs reveals several similarities, such as antioxidant and anti-inflammatory effects. However, Lemongrass offers additional benefits like enzymatic inhibition and lipid profile improvement, which are not typically addressed by standard medications (El-Sayed et al., 2013; Pari and Latha, 2005).

While conventional drugs are highly effective in lowering blood glucose levels, they

often come with side effects such as gastrointestinal disturbances and hypoglycemia. Lemongrass, on the other hand, has shown fewer adverse effects, making it a potentially safer alternative or complementary therapy (Gaba et al., 2020; Peter et al., 2021).

Combining Lemongrass with conventional antidiabetic drugs could enhance therapeutic outcomes by addressing multiple pathways involved in diabetes. This synergistic approach warrants further investigation (Pari and Latha, 2005).

4.8. Future Directions and Research Gaps

Large-scale clinical trials are essential to confirm the antidiabetic effects of Lemongrass and establish its role in diabetes management. These studies should focus on long-term outcomes and include diverse populations. Assessing the long-term safety of Lemongrass consumption, especially in high doses or as concentrated extracts, is crucial to ensure it does not cause adverse effects.

4.9. Integration into Conventional Therapies

Research should explore the potential for integrating Lemongrass into existing diabetes treatment protocols, examining possible interactions with conventional medications and identifying optimal combinations. Lemongrass demonstrates significant potential as a natural remedy for managing diabetes through its antioxidant (Balakrishnan et al., 2014; Costa et al., 2016), anti-inflammatory (Boukhatem et al., 2014), enzymatic inhibition (Borges et al., 2021), and insulin-sensitivity-enhancing properties. Preclinical and limited clinical evidence supports its use as an adjunct therapy (Villalobos et al., 2021).

4.10. Potential Implications for Diabetes Management

Given its multifaceted mechanisms and low incidence of side effects, Lemongrass could be a valuable addition to diabetes management strategies. Further research and clinical validation will be essential to fully harness its therapeutic potential and integrate it into mainstream medical practice. Figure 5 summarizes the mechanistics alleviated by lemongrass in diabetes (Bailey and Day, 1989; Garba et al., 2020). Furthermore, the results of lemongrass antidiabetic potential is sum-up in Table 1 and 2.

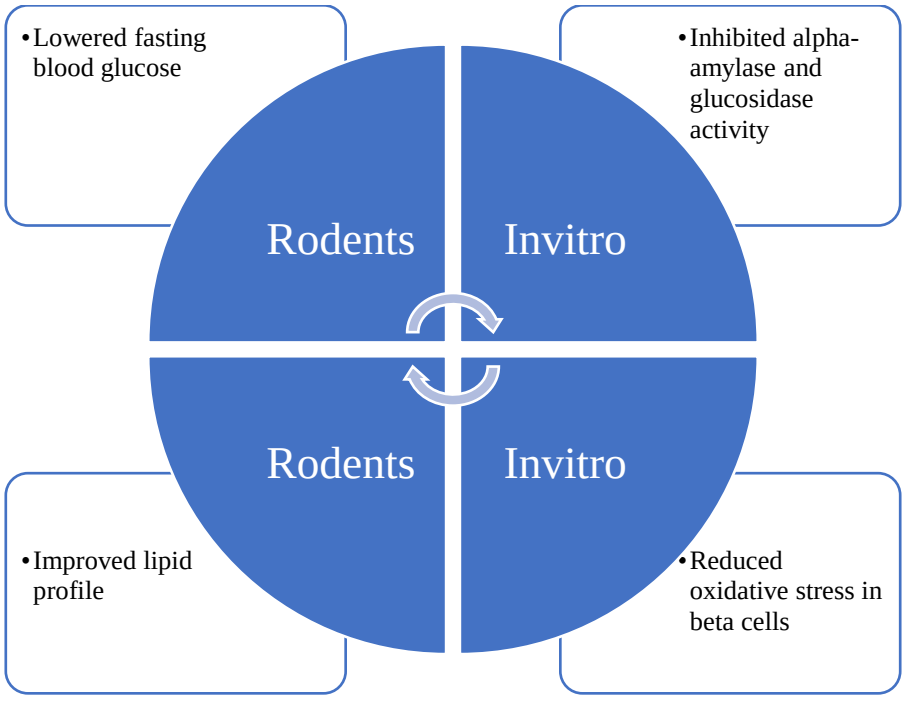

Fig. 5: Summary of Preclinical Studies on Lemongrass (Garba et al., 2020; Muala et al., 2021; Santoso et al., 2018).

Table 1: Clinical Trials on Lemongrass for Diabetes.

Study	Participants	Dosage Formulation	Key Outcomes
Trial A	50	Lemongrass tea	Improved glycemic control
Trial B	30	Lemongrass extract	Enhanced lipid metabolism
Trial C	40	Lemongrass supplement	Reduced inflammation and oxidative stress

Extracted from (Costa et al., 2016; Garba et al., 2020; Leite et al., 1986).

Table 2: Comparative Analysis of Lemongrass and Conventional Antidiabetic Drugs.

Parameter	Lemongrass	Conventional Drugs
Mechanisms	Antioxidant, anti-inflammatory, enzymatic inhibition, lipid improvement	Insulin secretion, insulin sensitivity, glucose absorption inhibition
Efficacy	Preliminary evidence suggests benefit	Well-documented and established
Side Effects	Few reported	Gastrointestinal issues, hypoglycemia
Long-Term Safety	Needs further study	Synergies with various drugs

(Ademuyiwa et al., 2015; Adeneye and Agbaje, 2007; Balakrishnan et al., 2014; Cheel et al., 2005; Ewenighi et al., 2013; Kumar et al., 2011; Leite et al., 1986).

This detailed review highlights the potential of Lemongrass as a natural remedy for enhancing diabetes resistance and managing hyperglycemia. With further research, Lemongrass could become a valuable component of holistic diabetes management strategies.

5. Overview of Findings: Expert opinion

Lemongrass (*Cymbopogon citratus*) has emerged as a promising natural remedy for diabetes management (Garba et al., 2020), supported by its rich phytochemical composition and multifaceted mechanisms of action. The bioactive compounds in Lemongrass, particularly citral, flavonoids, and phenolic acids, exhibit significant antidiabetic properties through antioxidant, anti-inflammatory, enzymatic inhibition, and lipid profile improvement effects (Borges et al., 2021; Costa et al., 2016; Kumar et al., 2011). This discussion delves into the implications of these findings, addresses current research gaps, and explores the potential integration of Lemongrass into conventional diabetes management protocols.

6. Conclusions and Future Directions

Lemongrass (*Cymbopogon citratus*) shows significant potential as a natural remedy for diabetes management due to its antioxidant, anti-inflammatory, enzymatic inhibition, and lipid-modulating properties. Preliminary preclinical and clinical studies suggest that Lemongrass can improve glycemic control and lipid profiles, offering a complementary approach to conventional diabetes treatments. Despite these promising findings, further large-scale clinical trials are essential to confirm its efficacy and safety.

Future research should focus on standardizing dosages and formulations, understanding long-term safety, and exploring potential synergistic effects with conventional medications. Additionally, elucidating the detailed mechanisms of action and identifying other bioactive compounds in Lemongrass will be crucial for maximizing its therapeutic potential. Integrating Lemongrass into holistic diabetes management strategies could enhance patient outcomes, providing a natural and accessible option for managing this chronic condition. As research advances, Lemongrass may become a valuable component of comprehensive diabetes care, contributing to improved health and quality of life for diabetic patients.

Data Availability: The data and materials supporting the conclusions of this article are included within the article.

Authors contribution: Attiqa Naz, Majid Khan, Sumbal Kibria, Mehrin Shirazi, Nida Iftikhar, and Tanzeela Ghani have written different chapters of the article under the supervision of Attiqa Naz. All authors approved the final version.

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