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Antidiabetic Potentials of Ginger, Clove, and Dandelion Plants

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ABSTRACT:
Purpose: Diabetes mellitus is a prevalent metabolic disorder characterized by impaired insulin secretion, insulin resistance, and persistent hyperglycemia. In recent years, increasing attention has been directed toward plant-derived compounds due to their diverse biological activities and comparatively lower risk of adverse effects. This review aims to evaluate the antidiabetic potential of ginger (*Zingiber officinale*), clove (*Syzygium aromaticum*), and dandelion (*Taraxacum officinale*)
Material and Methods: A comprehensive literature review was conducted using published in vitro, in vivo, and limited clinical studies investigating the effects of ginger, clove, and dandelion on glucose metabolism and diabetes-related pathways. Relevant studies were analyzed to assess proposed mechanisms of action and therapeutic relevance.
Results: The reviewed studies indicate that these medicinal plants may exhibit hypoglycemic effects through multiple mechanisms, including inhibition of α-amylase and α-glucosidase activities, enhancement of insulin secretion, and attenuation of oxidative stress and inflammatory responses. Experimental and animal studies report promising outcomes; however, evidence from human clinical trials remains insufficient.
Conclusion: Current findings suggest that ginger, clove, and dandelion may serve as complementary agents in diabetes management. Nevertheless, further well-designed clinical studies are required to confirm their long-term safety, efficacy, and optimal therapeutic dosage in humans.

Keywords: *Diabetes mellitus; zingiber officinale; ginger; syzygium aromaticum; clove; taraxacum officinale*

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INTRODUCTION

Rapid technological advancements, sedentary lifestyles, increased consumption of ultra-processed foods, and environmental factors have substantially contributed to the global rise in metabolic diseases. Among these, Type 2 Diabetes Mellitus (T2DM) has emerged as one of the most prevalent and impactful conditions, significantly impairing quality of life worldwide (Güvenç, 2024). According to the most recent data from the International Diabetes Federation Diabetes Atlas (IDF), approximately 589 million adults aged 20–79 years are currently living with diabetes, corresponding to nearly 11.1% (1 in 9) of the global adult population, and this number is projected to reach 853 million by 2050 (IDF, 2025). Similarly, the World Health Organization (WHO) reports that the global burden of diabetes has increased dramatically over recent decades, reaching approximately 830 million individuals worldwide as of the most recent estimates, highlighting diabetes as one of the fastest-growing global health challenges. Notably, more than 90% of all diabetes cases are classified as T2DM and are largely driven by modifiable risk factors such as obesity, physical inactivity, and urbanization (WHO, 2025). Consistent with these epidemiological data, the American Diabetes Association (ADA) emphasizes that more than 90% of diabetes cases are classified as T2DM and are primarily driven by modifiable risk factors, including obesity, physical inactivity, and unhealthy dietary patterns (ADA, 2025).

These data collectively indicate that the global prevalence of diabetes continues to rise at an alarming rate, underscoring the urgent need for effective prevention strategies, early diagnosis, and innovative therapeutic approaches to mitigate its growing health and economic burden.

Diabetes mellitus is a heterogeneous group of metabolic disorders characterized by chronic hyperglycemia resulting from defects in insulin secretion, insulin action, or both (Petersmann et al., 2019). The disease primarily manifests as two major forms: Type 1 diabetes and Type 2 diabetes. Type 1 diabetes typically develops early in life and is caused by autoimmune destruction of pancreatic insulin-producing β-cells (Udler et al., 2019). In contrast, T2DM generally occurs later in adulthood and is mainly associated with insulin resistance and impaired metabolic regulation. Genetic susceptibility plays a crucial role in the development of T2DM; however, environmental factors such as unhealthy dietary patterns and physical inactivity significantly exacerbate disease risk (Zheng et al., 2018).

The diagnosis of T2DM is commonly based on fasting plasma glucose (FPG) and glycated hemoglobin (HbA1c) measurements. According to the ADA, diabetes is diagnosed when HbA1c levels exceed 6.5% or when FPG values are above 126 mg/dL (7.0 mmol/L) (ElSayed et al., 2023 ; ADA, 2025). Poorly controlled T2DM can lead to severe microvascular and macrovascular complications. Standard treatment strategies include lifestyle modifications such as dietary regulation and physical activity, along with pharmacological interventions including oral hypoglycemic agents and insulin therapy when required. Despite their effectiveness, conventional treatments may be associated with side effects, high costs, and long-term adherence challenges.

In recent years, complementary and alternative therapeutic approaches, particularly herbal medicines and plant-derived products, have attracted growing interest for diabetes management. Plants have played a central role in traditional medical systems, including Traditional Chinese Medicine, Ayurveda, and various herbal practices across different cultures. In developing countries, herbal remedies continue to be widely used for managing chronic diseases (Bodeker et al., 2005). However, inappropriate or uncontrolled use of medicinal plants may pose safety concerns, including toxicity, allergic reactions, and herb–drug interactions (Vitalone et al., 2011).

Herbal therapies have long been employed in the management of diabetes across diverse regions, including the Middle East, where plants such as fenugreek (*Trigonella foenum-graecum*), cinnamon (*Cinnamomum cassia*), ginger (*Zingiber officinale*), turmeric (*Curcuma longa*), and black cumin (*Nigella sativa*) are commonly used for their potential antidiabetic effects (Rahul and Nandhakumar, 2022; Almubayedh et al., 2018; Chaphalkar, 2024). Despite their widespread use, comprehensive and evidence-based evaluations of many antidiabetic plants remain limited, highlighting a critical gap in the current literature.

Therefore, the objective of this review is to compile and critically evaluate existing scientific evidence regarding the antidiabetic potential of three medicinal plants—ginger (*Zingiber officinale*), clove (*Syzygium aromaticum*), and dandelion (*Taraxacum officinale*)—with a focus on their proposed mechanisms of action and therapeutic relevance in diabetes management.

1.1. The Role of *α-Amylase* and *α-Glucosidase* Enzymes in Diabetes

T2DM is a metabolic disorder characterized primarily by postprandial hyperglycemia. The treatment of diabetes, which leads to disturbances in carbohydrate, lipid, and protein metabolism, is to control or reduce postprandial hyperglycemia. Nutritional strategies aimed at improving postprandial glycemia by reducing glucose intake from digestible carbohydrates are recommended for patients with early-stage diabetes before initiating pharmacological treatment (Ch'ng et al., 2019). Carbohydrate digestion is carried out in the gastrointestinal tract via specific hydrolase enzymes that break down starch and disaccharides into smaller sugar molecules. *α-Amylase* (1,4-α-D-glucan-glucanohydrolase, EC 3.2.1.1) and *α-glucosidase* (EC

3.2.1.20) are two pivotal enzymes responsible for digestion of carbohydrates (Dona et al., 2010). *α-amylase*, an endo-amylase which is synthesized and released by the pancreas and the salivary glands, hydrolyzes complex polysaccharide molecules, including starch and glycogen into smaller oligosaccharides such as maltose (Figure 1). Following this breakdown, the final hydrolysis step is performed by α-glucosidase, an enzyme situated on the small intestinal brush border, which cleaves the oligosaccharides into glucose, making them absorbable (Bischoff, 1994).

α-Amylase inhibitors act as dietary starch blockers by suppressing starch breakdown and thereby reducing postprandial glucose absorption in the gastrointestinal (GI) tract. *α-Glucosidase* inhibitors, on the other hand, delay the liberation of glucose from complex carbohydrates in the diet and thus delay glucose absorption, thus suppressing hyperglycemia (Kashtoh and Baek, 2023). Inhibitors targeting *α-amylase* and *α-glucosidase* are viewed as a practical prophylactic strategy against hyperglycemia. By delaying the ultimate steps of carbohydrate breakdown, these compounds effectively mitigate the rapid influx of glucose into the bloodstream.

However, conventional synthetic inhibitors of these enzymes are frequently associated with undesirable gastrointestinal complications, including bloating, abdominal discomfort, and diarrhea (Chiasson et al., 2002). Consequently, plant-based glucosidase inhibitors have attracted increasing significance in diabetes therapy, owing to their generally superior tolerability and beneficial therapeutic attributes. Recent investigations confirm that various phenolic constituents extracted from botanicals (for instance, ginger, clove, and cinnamon) exhibit potent activity as natural antagonists of *α-amylase* and *α-glucosidase* (Sales et al., 2012). This creates a potential area for both functional food development and phytotherapeutic approaches.

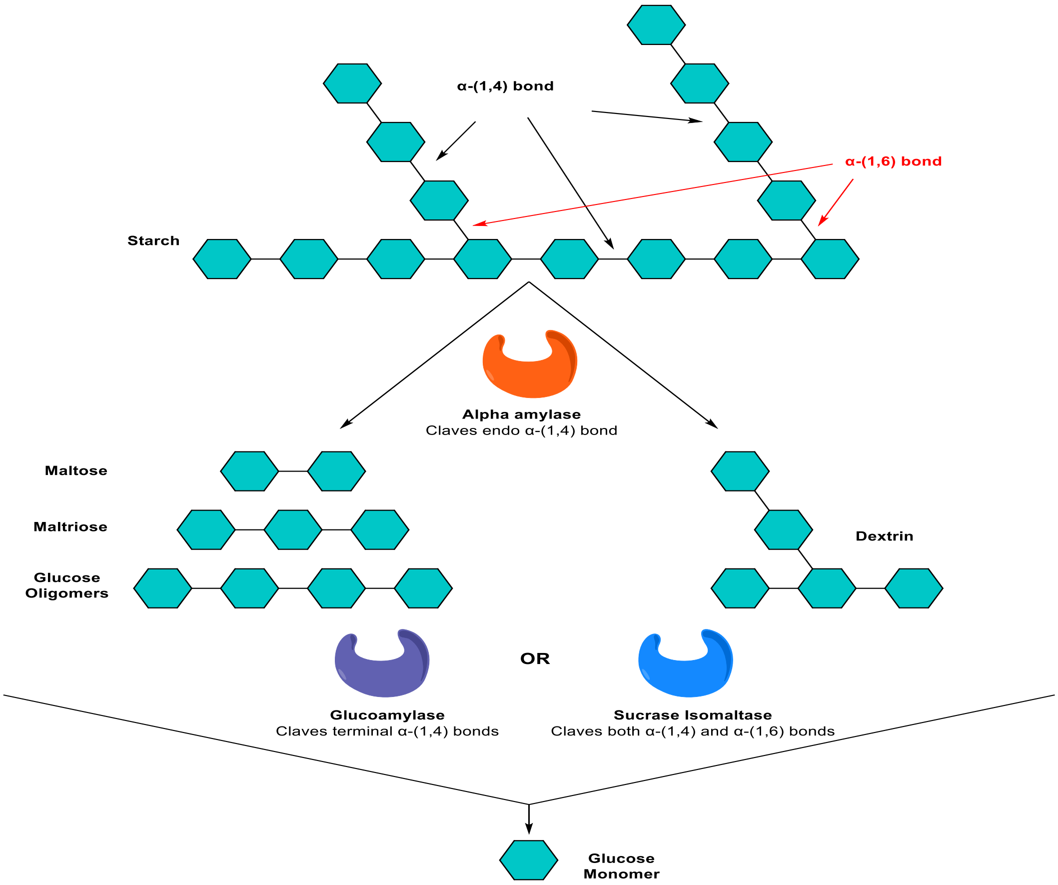

Figure 1. Hydrolysis of carbohydrates (Nelson and Cox, 2017; Murray et al., 2018).

1.2. Antidiabetic Potential of Ginger (*Zingiber Officinale*)

Ginger (*Zingiber officinale*) is a perennial herbaceous species classified within the Zingiberaceae family. Scientifically, it is a perennial plant, *Zingiber officinale Roscoe*. Ginger consists of a false stem, also known as a root, yellow flowers, and tuberous rhizomes (Mahomoodally et al., 2021). The rhizomes of the plant are highly aromatic and have been extensively utilized as both a culinary spice and a traditional medicinal agent (Semwal et al., 2015) (Figure 2). Today, ginger is widely cultivated in approximately 50 countries, mostly in tropical and subtropical regions, including India, China, and Nigeria, for consumption as a herb, spice, and dietary supplement (Mahomoodally et al., 2021; Zhang et al., 2021).

Figure 2. Ginger (*Zingiber Officinale*) Root and Powder

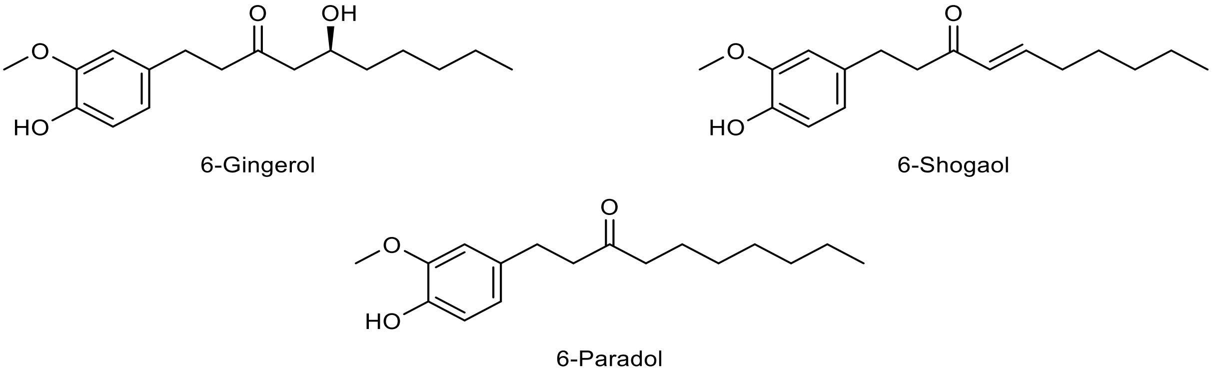

Figure 3. Active Ingredients of Ginger

The rhizomes of ginger are characterized by a highly complex chemical composition, where carbohydrates (50-70%) and lipids (3-8%) form the bulk of its dry weight. Its bioactivity stems primarily from two main classes of compounds: terpenes and phenolics. Zingiberene, β-*bisabolene*, α-*farnesene*, β-*sesquiphelandrene*, and α-*curcumen* constitute the principal terpene components of the plant. The phenolic fraction, which comprises gingerol, paradols, and shogaol, is particularly significant. Notably, gingerol (23–25%) and shogaol (18–25%) are the most abundant of these active phenolic compounds (Figure 3).

Beyond these major components, the rhizome also contains a variety of other essential nutrients and substances, such as amino acids, crude fiber, ash, protein, phytosterols, specific vitamins (e.g., nicotinic acid and vitamin A), and minerals (Mahomoodally et al., 2021; Zhang et al., 2021).

The antidiabetic effects of ginger are attributed to the following mechanisms (Figure 4):

- Increasing insulin sensitivity,
- Increasing glucose uptake and promoting the expression of glucose transporters (GLUT-4),
- Inhibiting enzymes involved in digestion, including *α-amylase* and *α-glucosidase*,
- Reducing inflammation and oxidative stress (Rahimlou et al., 2020).

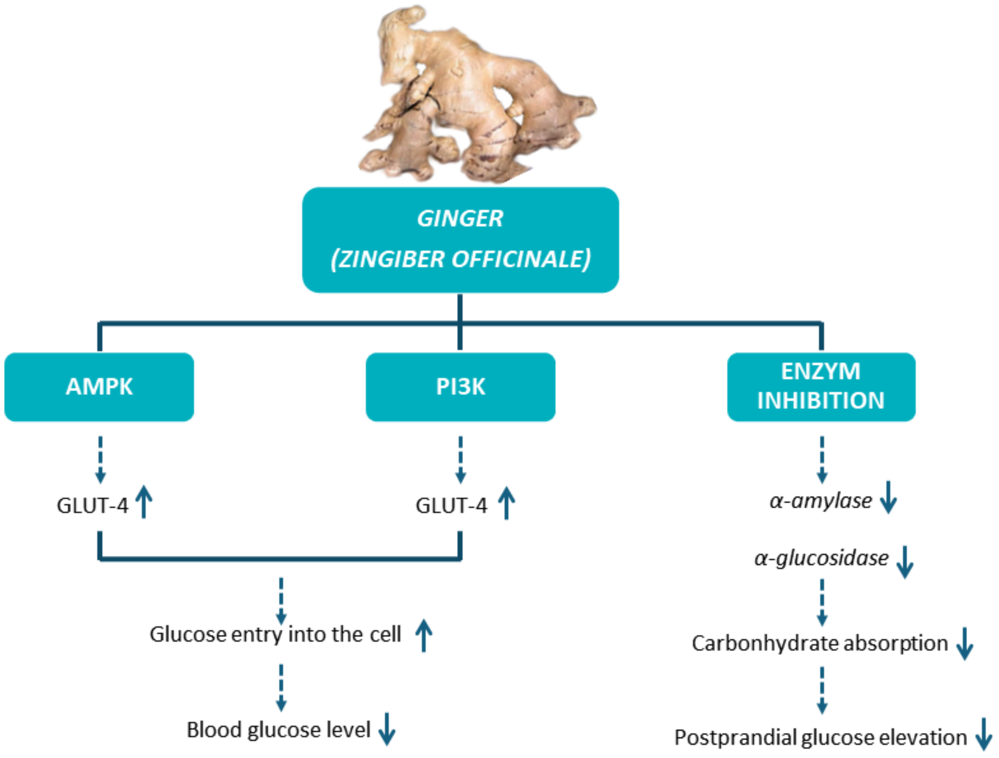

Figure 4. Mechanisms of Antidiabetic Action of Ginger (*Zingiber Officinale*)

Oral intake of ginger extract or powder has been associated with improvements in fasting blood glucose, HbA1c, and insulin resistance in animal models and human models clinical studies (Mahluji et al., 2013; Mozaffari-Khosravi et al., 2014). Furthermore, several systematic reviews have demonstrated the potential effects of ginger supplementation on glycemic control, lipid profiles, inflammatory markers, and oxidative stress in affected individuals with diabetes, hyperlipidemia, arthritis, neurological diseases, asthma, and stroke (Morvaridzadeh et al., 2021; Pourmasoumi et al., 2018).

Research has also shown that ginger juice demonstrated therapeutic potential against diabetes when tested in the established alloxan-induced rat model (Badreldin et al., 2008). Ginger juice treatment was observed to significantly lower fasting glucose while enhancing insulin secretion in rats with streptozotocin-induced type 1 diabetes (Asha et al., 2011). Al-Amin et al. also found that ginger possesses hypoglycemic, hypocholesterolemic, and hypolipidemic potential. Raw ginger administration was shown to mitigate proteinuria in experimental diabetic models (Al-Amin et al. 2006).

Another study the extract showed activity against diabetes in a streptozotocin (STZ) induced rat model. Following the ingestion of ginger extract demonstrated a significant dose-dependent antihyperglycemic effect, with a significant reduction in plasma glucose levels at the highest dose (67.85%). Furthermore, ginger treatment resulted in significant increases in the activities of key enzymes of the glycolysis pathway, such as glucokinase, phosphofructokinase, and pyruvate kinase, resulting in more efficient glucose metabolism in peripheral tissues. Glycogen accumulation in the kidneys was reduced, while glycogen levels in the liver and skeletal muscle were improved. The findings suggest that ginger has the potential to improve the metabolic disorders caused by diabetes through its effects on glucose homeostasis (Bidemi Abdulrazaq et al., 2012).

A detailed in vitro study examined the effects of *Zingiber officinale* extract on glucose metabolism in C2C12 myoblast cells. This research clarified the signaling pathways regulating the expression of the glucose transporter protein GLUT-4. The findings suggest that ginger extract primarily transports GLUT-4 to the cell membrane via the AMP-activated protein kinase (AMPK) pathway, with a secondary effect via the phosphoinositide 3-kinase (PI3K) pathway.

The more pronounced decrease in GLUT-4 levels in the presence of an AMPK inhibitor supports the predominant role of the AMPK pathway in the antidiabetic effects of ginger. Consequently, these data suggest that ginger could be considered a complementary phytotherapeutic agent for diabetes management by increasing glucose uptake in muscle cells (Tajik Kord et al., 2020) (Table 1).

Table 1. Pharmacological Activities and Antidiabetic Effects of *Zingiber officinale*

Pharmacological Activity	Results / Findings	References
Increasing insulin sensitivity	Improves insulin sensitivity and enhances glucose uptake in peripheral tissues.	Rahimlou et al., 2020
Upregulation of GLUT-4 expression	Promotes translocation of GLUT-4 to the cell membrane via AMPK and PI3K signaling pathways in C2C12 myoblast cells.	Tajik Kord et al., 2020.
Inhibition of α-amylase and α-glucosidase	Inhibits carbohydrate-digesting enzymes, contributing to reduced postprandial blood glucose levels.	Rahimlou et al., 2020
Anti-inflammatory and antioxidant activity	Reduces oxidative stress and inflammation, improving insulin resistance and metabolic balance.	Rahimlou et al., 2020; Morvaridzadeh M. et al., 2021
Antihyperglycemic effect in diabetic models	Oral administration of ginger extract reduces fasting glucose and HbA1c levels in both animal and human studies.	Mahluji et al., 2013; Mozaffari-Khosravi et al., 2014
Hypoglycemic and hypolipidemic activity	Raw ginger mitigates proteinuria, lowers cholesterol and lipid levels, and enhances insulin secretion in diabetic rats.	Al-Amin et al., 2006; Asha B. et al., 2011
Enzymatic modulation of glycolysis	Increases glucokinase, phosphofructokinase, and pyruvate kinase activity, enhancing glucose metabolism and glycogen storage in the liver and muscle.	Bidemi Abdulrazaq et al., 2012.
Improvement in oxidative stress and lipid profile	Ginger supplementation improves lipid parameters and oxidative stress markers in diabetic and hyperlipidemic subjects.	Pourmasoumi et al., 2018; Morvaridzadeh et al., 2021
Antidiabetic activity in alloxan and STZ models	Ginger juice exhibits significant antihyperglycemic effects and enhances pancreatic insulin secretion.	Badreldin et al., 2008; Asha et al., 2011

1.3. Antidiabetic Potential of Clove (Syzygium Aromaticum)

Clove (*Syzygium aromaticum*) is a plant belonging to the Myrtaceae family, used as a spice and medicinal plant. Cloves have been used as a spice in ancient China for over 2,000 years and were included on China's first medicinal food list in 2002. Emerging evidence suggests that the fruits, seeds, and leaves of *Syzgium aromaticum* also contain bioactive compounds (Kumar et al., 2022) (Figure 5).

Thanks to the flavonoids, phenolic acids, tannins, and essential oils it contains, Clove exhibits potential in modulating oxidative stress and improving insulin sensitivity regulating insulin metabolism. Experimental studies have shown that clove extract lowers blood glucose levels, increases insulin secretion, and protects pancreatic β-cell function (Sivashanmugam et al., 2018).

The antidiabetic effects of cloves are evaluated through the following mechanisms (Figure 6):

- Suppression of *α-amylase* and *α-glucosidase* activities ,
- Increased insulin sensitivity,
- Prevention of oxidative damage in pancreatic β-cells,
- Regulatory effects on adipogenesis and glucose transport pathways (Kuroda et al., 2012).

Clove ethanol extract promotes glucose uptake and insulin release in muscle cells by decreasing serine phosphorylation on insulin receptor substrate-1 while simultaneously increasing phosphorylation of protein kinase B (PKB) and glycogen synthase kinase-3 beta (GSK-3β).

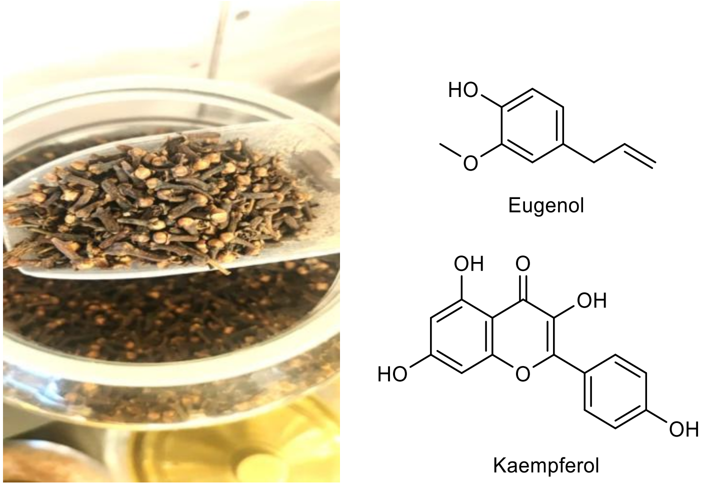

Figure 5. Clove (*Syzygium Aromaticum*) and Active Ingredients

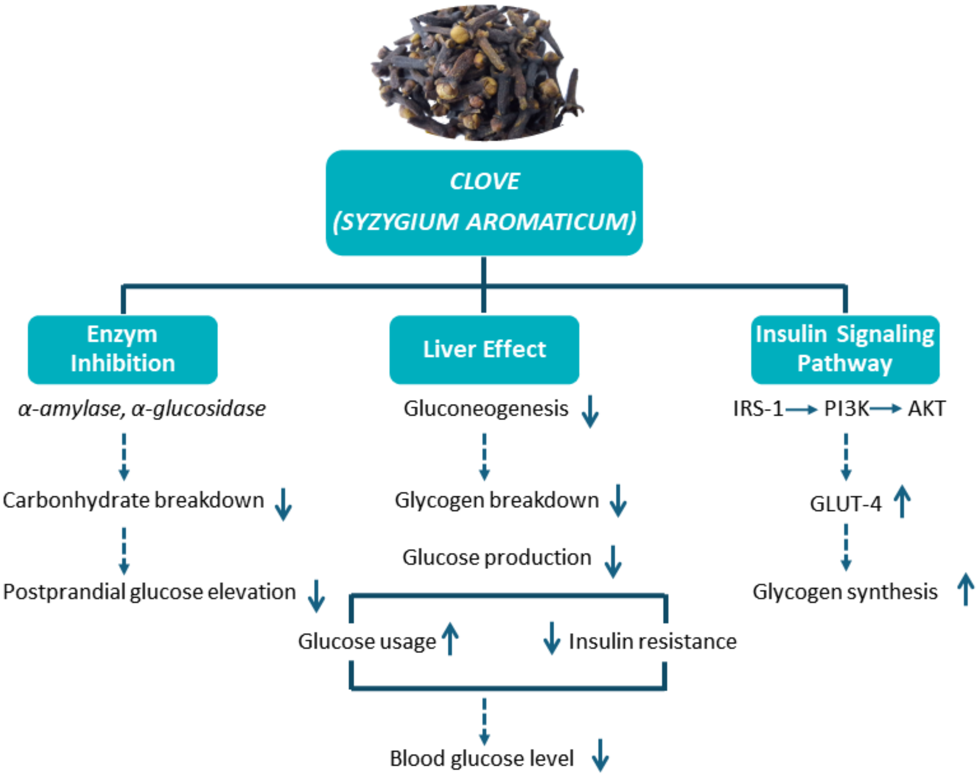

Figure 6. Mechanisms of Antidiabetic Action of Clove (*Syzygium Aromaticum*)

In addition, Clove extract (CE) has been shown to activate metabolic regulatory genes such as AMP-activated protein kinase, sirtuin 1 (SIRT1) and peroxisome proliferator-activated receptor gamma coactivator 1-alpha (PGC1-α). CE reduces hepatic glycogen breakdown and suppresses gluconeogenesis by exhibiting an inhibitory effect on glycogen phosphorylase-b enzyme. These effects suggest that CE may be as effective as insulin in lowering blood glucose and HbA1c levels. In addition, dehydrodienol and dehydrodienol-B compounds contained in CE regulate adipocyte differentiation and glucose homeostasis by triggering peroxisome proliferator-activated receptor gamma (PPAR-γ) receptor activation (Xue et al., 2022).

Syzygium aromaticum (clove) contains biological compounds that act on fundamental mechanisms involved in the pathophysiology of diabetes, such as oxidative stress, inflammation, and insulin resistance. In particular, its main active component, eugenol, and its derivatives inhibit carbohydrate metabolism carbohydrate-hydrolyzing enzymes such as *α-amylase* and *α-glucosidase*, reducing postprandial glucose elevation and supporting glycemic control. Furthermore, the antidiabetic effects of clove oil include regulating bowel movements, increasing the activity of digestive enzymes, and balancing the gut microbiota. These mechanisms may support glycemic control by positively affecting glucose absorption and insulin sensitivity (Haro-González et al., 2021). Furthermore, isoeugenol exhibits both anticholinergic and antidiabetic effects and has the potential to modulate insulin signaling pathways.

The antioxidant effect and anti-inflammatory effect of clove extract may protect pancreatic β-cell function by reducing diabetes-related cellular damage (Amir et al., 2022). These findings support the evaluation of *Syzygium aromaticum* as a complementary phytotherapeutic agent in the management of diabetes. However, more detailed compound-based and human-based future studies should aim to elucidate the clinical validity of these effects (Table 2).

Table 2. Pharmacological Activities and Antidiabetic Effects of *Syzygium aromaticum*

Pharmacological Activity	Results / Findings	References
Inhibition of *α-amylase* and α-glucosidase	Suppresses key carbohydrate-hydrolyzing enzymes, reducing postprandial glucose elevation and supporting glycemic control.	Kuroda et al., 2012; Haro-González et al., 2021
Enhancement of insulin sensitivity	Improves insulin metabolism, increases insulin secretion, and enhances glucose uptake in peripheral tissues.	Sivashanmugam et al., 2018; Xue et al., 2022
Protection of pancreatic β-cell function	Prevents oxidative and inflammatory damage in pancreatic β-cells, maintaining insulin secretion capacity.	Sivashanmugam et al., 2018; Amir et al., 2022
Regulation of adipogenesis and glucose transport	Dehydrodienol and dehydrodienol-B compounds activate PPAR-γ receptors, regulating adipocyte differentiation and glucose homeostasis.	Xue et al., 2022
Activation of metabolic regulatory pathways	Clove ethanol extract activates AMPK, SIRT1, and PGC1α pathways, increasing insulin sensitivity and improving glucose metabolism.	Xue et al., 2022
Reduction of hepatic glycogen breakdown	Inhibits glycogen phosphorylase-b, suppressing gluconeogenesis and reducing blood glucose and HbA1c levels.	Xue et al., 2022
Antioxidant and anti-inflammatory activity	Reduces oxidative stress and inflammation, supporting pancreatic protection and overall metabolic balance.	Amir et al., 2022; Haro-González et

1.4. Antidiabetic Potential of Dandelion (*Taraxacum Officinale*)

Taraxacum officinale, often referred to as dandelion, is a perennial herbaceous species classified under the Asteraceae family. Approximately 40 cm tall, this plant is characterized by its yellow-orange flowers and toothed leaves. The name “*Taraxacum*” is derived from the Greek words “taraxos” (discomfort) and “akos” (cure) (Di Napoli and Zucchetti, 2021). The roots and young shoots of the plant have traditionally been employed in herbal medicine for their therapeutic properties (Grieve, 1931; Rasool and Sharma, 2014; Stewart-Wade et al., 2002).

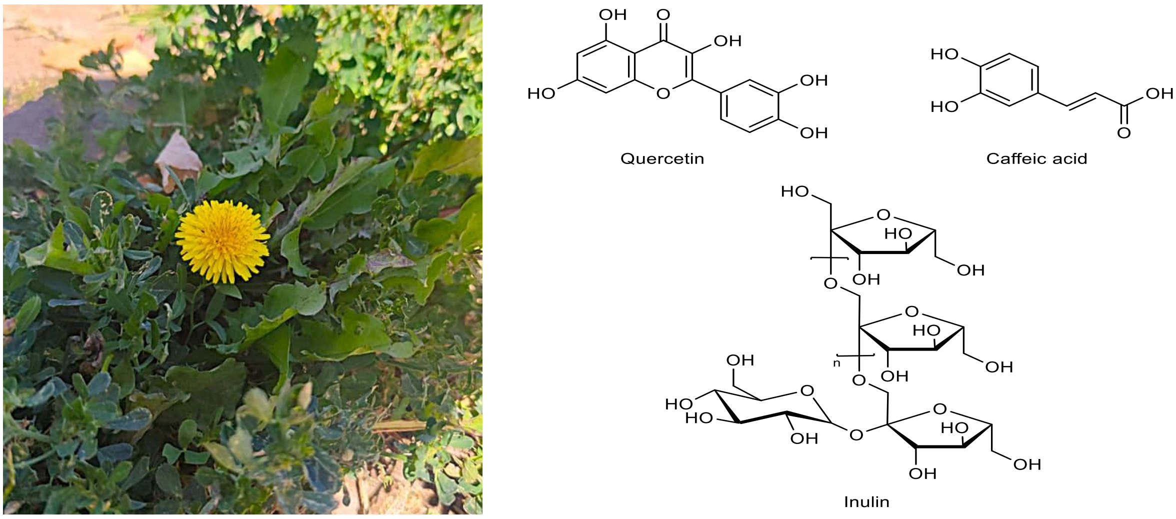

Figure 7. Dandelion (*Taraxacum Officinale*) Plant and Active Ingredients

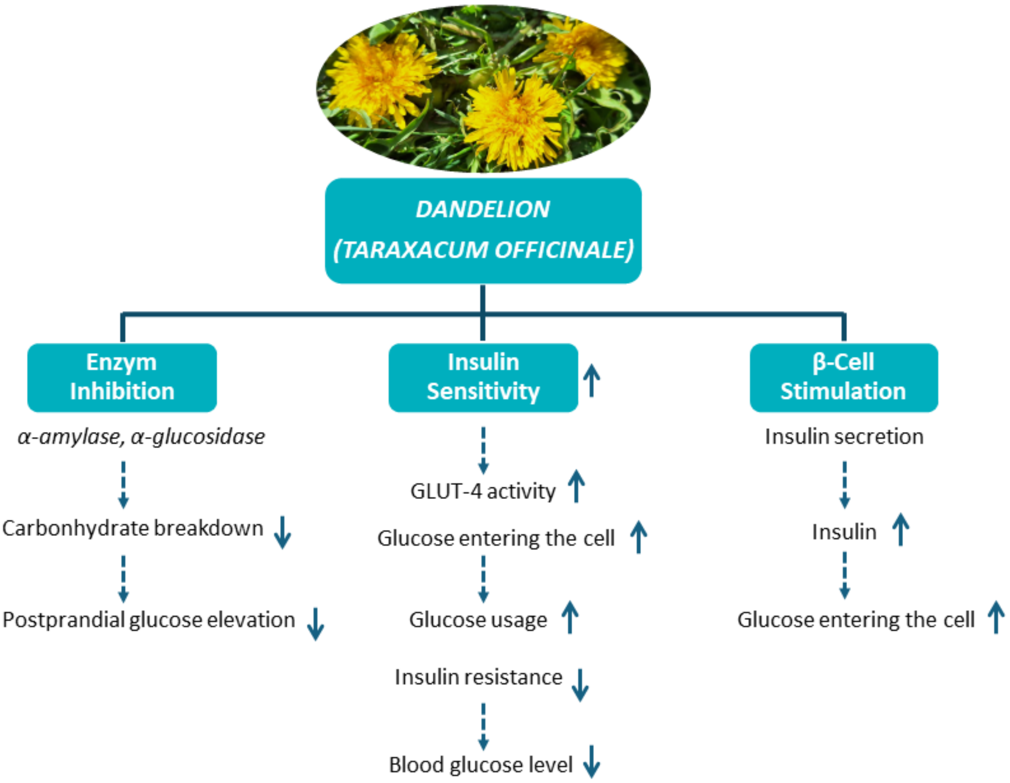

Figure 8. Mechanisms of Antidiabetic Action of Dandelion (*Taraxacum Officinale*)

Analyses have revealed that dandelions contain high levels of fiber, minerals, vitamins, and essential fatty acids (Escudero et al., 2003). The young leaves of the plant are widely consumed in salads, beverages, and vegetable dishes due to their important and high nutritional composition.

The rich phytochemical components found in the flower, leaf, stem and root part of dandelion confer various pharmacological properties to the plant. These components include carotenoids; flavonoids (quercetin, chrysoeriol, luteolin-7-glucoside); phenolic acids (caffeic acid, chlorogenic acid, cichoric acid); polysaccharides (especially inulin); sesquiterpene lactones *(taraxinic acid, taraxacoside, 11*β*,13-dihydrolactusin, ixerin D, taraxacolid-O-*β*-glucopyranoside*); sterols (*taraxasterol,* β*-sitosterol, stigmasterol*) and triterpenes (Amin Mir et al., 2013; Singh et al., 2008) (Figure 7).Pharmacological investigations suggest that *Taraxacum officinale* plays a significant role in glycemic regulation. Bioactive compounds isolated from the plant have demonstrated hypoglycemic activity, primarily through the inhibition of α-glucosidase and α-amylase enzymes (Choi et al., 2018; Guo et al., 2019). Evidence from animal studies indicates that this effect may be mediated by enhanced insulin secretion from pancreatic β-cells (Akhtar et al., 1985). In addition, leaf extracts of *Taraxacum officinale* have been observed to lower fasting blood glucose levels and improve insulin sensitivity (Davaatseren et al., 2013). Complementary in vitro studies further reveal that the plant extract stimulates insulin release from β-cells (Hussain et al., 2004) (Figure 8) (Table 3).

In conclusion, *Taraxacum officinale* is a plant noted for its rich phytochemical content, not only for its nutritional properties but also for its potential effects on glycemic control. Therefore, it holds an important place in both traditional medicine and modern phytotherapeutic approaches.

Table 3. Pharmacological Activities and Antidiabetic Effects of *Taraxacum officinale*

Pharmacological Activity	**Results / Findings**	**References**
Inhibition of *α-amylase* and *α-glucosidase*	Suppresses carbohydrate-digesting enzymes, reducing postprandial blood glucose levels.	Choi et al., 2018; Guo et al., 2019
Enhancement of insulin secretion	Stimulates insulin release from pancreatic β-cells, improving glucose regulation.	Akhtar et al., 1985; Hussain et al., 2004
Improvement of insulin sensitivity	Leaf extracts decrease fasting blood glucose and enhance insulin sensitivity in diabetic animal models.	Davaatseren et al., 2013
Regulation of glucose metabolism	Promotes peripheral glucose utilization and hepatic glycogen synthesis, contributing to improved glucose homeostasis.	Akhtar et al., 1985; Davaatseren et al., 2013
Antioxidant and anti-inflammatory activity	Phenolic acids and flavonoids reduce oxidative stress and inflammation associated with diabetes.	Singh et al., 2008; Amin Mir et al., 2013
Nutrient-rich composition	Contains high levels of fiber, minerals, vitamins, and essential fatty acids, supporting metabolic health.	Escudero et al., 2003
Key phytochemical constituents	Includes carotenoids, flavonoids (quercetin, luteolin), phenolic acids (chlorogenic, cichoric), polysaccharides (inulin), and sesquiterpene lactones.	Amin Mir et al., 2013; Singh et al., 2008
Hypoglycemic activity	Demonstrates dose-dependent antihyperglycemic effects through enzymatic inhibition and β-cell stimulation.	Choi et al., 2018; Guo et al., 2019; Hussain et al., 2004
Traditional and modern relevance	Used in herbal medicine and modern phytotherapy for its glycemic control and metabolic support properties.	Grieve, 1931; Rasool and Sharma, 2014

MATERIAL and METHODS

This review was conducted through a comprehensive and systematic evaluation of previously published scientific studies investigating the antidiabetic effects of selected medicinal plants. The literature search focused specifically on ginger (*Zingiber Officinale*), clove (*Syzygium Aromaticum*), and dandelion (*Taraxacum Officinale*), which have been traditionally used and scientifically explored for their potential roles in diabetes management.

Relevant publications were retrieved from internationally recognized electronic databases, including PubMed, Scopus, Web of Science, and Google Scholar. The search strategy employed a combination of Medical Subject Headings (MeSH) terms and free-text keywords such as “diabetes mellitus,” “type 2 diabetes,” “antidiabetic activity,” “ginger,” “clove,” “dandelion,” “*α-amylase* inhibition,” “α-glucosidase inhibition,” “insulin resistance,” and “oxidative stress.” Articles published in English up to 2025 were considered for inclusion.

Studies were included if they were original research articles (in vitro, in vivo, or clinical studies) evaluating the antidiabetic, hypoglycemic, antioxidant, or anti-inflammatory effects of the selected plants and reporting clearly defined experimental methods and measurable outcomes such as fasting blood glucose, HbA1c, insulin sensitivity, or enzyme inhibition. Only full-text articles published in peer-reviewed journals were included. Studies were excluded if they were review articles, meta-analyses, conference abstracts, editorials, or case reports; if they lacked sufficient methodological detail or reproducible data; if they were not directly related to diabetes or glucose metabolism or if they represented duplicate or overlapping publications.

Following the initial database search, titles and abstracts were screened for relevance, and full-text articles of potentially eligible studies were assessed according to the inclusion and exclusion criteria. Due to substantial heterogeneity in study designs, methodologies, and outcome variables, the extracted data were analyzed qualitatively and synthesized descriptively, and no meta-analysis or quantitative statistical pooling was performed (Table 4).

Table 4. Inclusion and Exclusion Criteria

INCLUDED	EXCLUDED
Original research (in vitro, in vivo, clinical studies)	Review articles and meta-analyses
Studies on *Zingiber officinale*, *Syzygium aromaticum*, *Taraxacum officinale*	Irrelevant plant species
Studies reporting glycemic/metabolic outcome	Studies not related to diabetes/metabolism
English language	Non-English publications
Full-text available articles	Abstract-only or incomplete data
Measurable outcomes (FBG, HbA1c, insulin, enzyme activity)	Duplicate or overlapping studies

DISCUSSION

This review highlights the antidiabetic potential of *Zingiber officinale*, *Syzygium aromaticum*, and *Taraxacum officinale*, three medicinal plants with diverse phytochemical profiles and mechanisms of action. Collectively, the literature indicates that these plants modulate key pathways involved in the pathophysiology of diabetes, including carbohydrate metabolism, oxidative stress, and insulin signaling (Salehi et al., 2019).

Zingiber officinale demonstrates one of the most consistent bodies of evidence among the three medicinal plants (Zhu et al., 2018). Its major phenolic constituents, gingerols and shogaols, exert glycemic control through multiple mechanisms, including inhibition of *α-amylase* and *α-glucosidase*, upregulation of GLUT-4 expression, and activation of AMPK-dependent signaling pathways (Van et al., 2023). Consistent with these mechanisms, both preclinical and clinical studies have reported significant improvements in fasting blood glucose, HbA1c levels, and insulin resistance (Mahluji et al., 2013; Zhu et al., 2018).

In particular, recent evidence from systematic reviews and meta-analyses conducted over the last five years (2021-2025) in the journal Frontiers in Pharmacology suggests that *Zingiber officinale* supplementation may significantly improve glycemic control in patients with type 2 diabetes by lowering fasting blood glucose and HbA1c levels, and may also have beneficial effects on inflammatory and oxidative stress markers. However, despite these promising results, high inter-study heterogeneity and variability in dosage, extraction methods, and intervention protocols continue to limit the strength of clinical recommendations and highlight the need for more standardized randomized controlled trials (Van et al., 2023; Schumacher et al., 2024; Paudel et al., 2025.).

Nevertheless, variability in extraction methods, dosages, and intervention durations remains a critical limitation, reducing the comparability and reproducibility of findings across studies (Zhu et al., 2018). Overall, although *Zingiber officinale* exhibits strong mechanistic and emerging clinical evidence, the most significant challenge remains the lack of standardization in clinical trial design and phytochemical characterization. Therefore, well-designed, standardized clinical trials are required to confirm its therapeutic efficacy and to establish evidence-based guidelines for its use in glycemic management.

Syzygium aromaticum exhibits notable antidiabetic potential, largely attributed to its high eugenol content and related phenolic constituents. Experimental evidence indicates that clove extracts exert antioxidant, anti-inflammatory, and insulin-sensitizing effects, while also improving glucose homeostasis through inhibition of carbohydrate-hydrolyzing enzymes such as *α-amylase* and *α-glucosidase* (Kuroda et al., 2012). Recent studies further support these findings, demonstrating that clove essential oil and extracts can reduce hyperglycemia in experimental diabetic models, primarily through enhancement of antioxidant defense systems and modulation of glucose metabolism-related pathways (Ruyati & Ruyati, 2024). In addition, emerging mechanistic evidence suggests that eugenol may contribute to metabolic regulation via attenuation of oxidative stress and improvement of insulin signaling, with involvement of pathways such as AMPK and PPAR-γ (Pandey et al., 2023). Recent literature indicates that *Syzygium aromaticum* and its major bioactive compound eugenol exhibit significant pharmacological activities, including antioxidant, anti-inflammatory, and antidiabetic effects, largely mediated through modulation of oxidative stress and metabolic signaling pathways (Nisar et al., 2021; Pandey et al., 2023).

However, despite these promising preclinical and mechanistic findings, clinical evidence in humans remains limited and insufficient to draw definitive conclusions regarding efficacy. Recent literature also highlights that eugenol undergoes rapid biotransformation, including glucuronidation and sulfation, leading to low systemic bioavailability and reduced in vivo exposure. This pharmacokinetic limitation contributes to the discrepancy between strong in vitro pharmacological activity and variable in vivo outcomes (Tavvabi-Kashani et al., 2024). Moreover, variability in extraction methods, phytochemical composition, and dosing regimens further reduces comparability and reproducibility across studies, posing additional challenges for clinical translation.

Overall, although *Syzygium aromaticum* demonstrates strong mechanistic and preclinical antidiabetic potential, its clinical application remains constrained by pharmacokinetic limitations and a persistent lack of standardized, well-designed human trials. Future research should therefore focus on improving bioavailability and conducting robust clinical investigations to validate its therapeutic efficacy.

Taraxacum officinale (dandelion) has recently gained increasing attention due to its diverse phytochemical composition and potential antidiabetic properties. The plant is rich in bioactive compounds such as inulin, flavonoids, phenolic acids, and sesquiterpene lactones, which collectively contribute to its metabolic regulatory effects. Recent experimental and review-based evidence suggests that dandelion extracts may improve glucose homeostasis by inhibiting carbohydrate-hydrolyzing enzymes, enhancing glucose uptake, and exerting antioxidant and anti-inflammatory activities relevant to diabetes pathophysiology (Kania-Dobrowolska & Baraniak, 2022; Fan et al., 2023). In addition, earlier findings support that *Taraxacum officinale* may contribute to glycemic regulation primarily through enzyme inhibition and β-cell stimulation, with its diverse phytochemicals demonstrating hypoglycemic and insulin-sensitizing effects in preclinical models (Fonyuy et al., 2016).

Recent preclinical studies further report that *Taraxacum officinale* root extracts can reduce fasting blood glucose levels and improve insulin sensitivity, potentially mediated by inulin-rich fractions and polyphenolic compounds (Li et al., 2021; Laila et al., 2025). Despite these promising findings, the current evidence base remains largely restricted to in vitro and animal studies and well-designed clinical trials in humans are still lacking. Moreover, variability in phytochemical composition depending on plant parts, extraction method and environmental conditions significantly affects reproducibility and standardization of results (Fan et al., 2023; Kania-Dobrowolska & Baraniak, 2022). Importantly, the bioavailability and metabolism of its active constituents remain insufficiently characterized, further limiting translation into clinical practice. Overall, although *Taraxacum officinale* demonstrates promising antidiabetic potential, its clinical application remains limited due to insufficient human evidence and incomplete pharmacokinetic understanding (Fonyuy et al., 2016; Laila et al., 2025).

Comparatively, *Zingiber officinale* benefits from the most robust clinical evidence, with recent systematic reviews and meta-analyses supporting its beneficial effects on glycemic control, including reductions in fasting blood glucose and HbA1c levels, as well as improvements in insulin resistance parameters (Schumacher et al., 2024). In contrast, *Syzygium aromaticum* and *Taraxacum officinale* are primarily supported by preclinical and mechanistic studies, with limited clinical validation in humans. Each plant targets distinct but complementary aspects of diabetes pathophysiology; ginger primarily enhances glucose uptake and insulin sensitivity through AMPK-mediated pathways, clove modulates oxidative stress and inflammatory responses via eugenol-driven mechanisms, and dandelion contributes to glycemic regulation through enzyme inhibition, β-cell modulation and improvement of insulin secretion (Fan et al., 2023; Nisar et al., 2021; Li et al., 2021).

This complementary pharmacological profile suggests potential synergistic applications of these medicinal plants, either in combination therapies or as functional food components for glycemic management. However, despite these promising mechanistic and preclinical findings, current evidence remains insufficient to support clinical recommendations, highlighting the need for well-designed, standardized randomized controlled trials to evaluate efficacy, safety, and optimal dosing strategies in humans (Laila et al., 2025).

A recent review emphasized that, although medicinal plant-derived compounds exhibit potent in vitro pharmacological activity, their clinical effectiveness is frequently constrained by poor bioavailability, extensive metabolic degradation, and limited intestinal permeability, underscoring a substantial discrepancy between in vitro and in vivo results (Chaves de Jesus et al., 2025). However, significant research gaps remain. Current evidence is limited by methodological heterogeneity, small sample sizes, and insufficient standardization of phytochemical characterization across studies, which collectively reduce the reproducibility and comparability of findings (Zhu et al., 2018). In addition, recent pharmacological and pharmacokinetic literature emphasizes that poor bioavailability, extensive metabolic degradation, and limited intestinal absorption of plant-derived bioactive compounds further constrain their clinical translation, despite promising in vitro and preclinical efficacy (Tavvabi-Kashani et al., 2024; Chaves de Jesus et al., 2025).

Future research should therefore prioritize well-designed, large-scale randomized controlled human trials to determine optimal dosing strategies, long-term safety, and pharmacokinetic profiles. Moreover, recent studies highlight the importance of investigating synergistic interactions among these medicinal plants and their active constituents, as well as potential drug–herb interactions that may influence therapeutic outcomes (Fan et al., 2023).

In summary, although preclinical and limited clinical evidence supports the antidiabetic potential of these medicinal plants, successful translation into clinical practice will require robust, interdisciplinary research integrating pharmacology, nutrition, and molecular biology, with a particular focus on standardization and pharmacokinetic optimization.

CONCLUSION

Current literature suggests that ginger, cloves and dandelion possess antidiabetic potential thanks to their rich phytochemical content. These plants may play a role in the prevention and management of diabetes via multiple biological mechanisms, including inhibition of α-amylase and α-glucosidase, improved insulin sensitivity, and attenuation of oxidative stress and inflammation.

However, most of the current findings are based on in vitro and animal models. Clinical studies are limited and the available data are insufficient to support the routine use of these plants as complementary agents in the treatment of diabetes. Therefore, future randomized controlled human studies with larger sample sizes are necessary to establish standards for dosage, administration method, safety and efficacy.

In conclusion ginger, cloves and dandelion hold promise as complementary phytotherapeutic agents in the management of diabetes. However, comprehensive, interdisciplinary research is needed to validate this potential at the clinical level.

Conflict of Interest

The authors declare that there is no conflict of interest.

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