Unveiling the Antidiabetic and Antihypertensive Potential of Terminalia catappa

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Abstract

Terminalia catappa (T. catappa), commonly referred to as the Indian almond tree, has garnered attention for its extensive medicinal applications across different cultures. This research aims to delve deeply into its antidiabetic and antihypertensive potentials, scrutinizing the bioactive compounds responsible for these effects, elucidating the underlying mechanisms of action, and evaluating its therapeutic efficacy through rigorous experimental methodologies. Our comprehensive analysis suggests that T. catappa holds significant promise as a natural founding therapeutic agenst for controlling diabetes and hypertension, warranting further clinical investigations to validate these findings and facilitate the development of novel treatment strategies.

Introduction

Background

Diabetes mellitus (DM) and hypertension (HTN) are among the most prevalent chronic diseases worldwide, significantly contributing to morbidity and mortality rates. Due to the problem in the insulin secretion diabetes characterized as a persistent hyperglycemia, insulin major action, or bothof them, leading to severe complications such as cardiovascular diseases, neuropathy, nephropathy, and retinopathy [1]. HTN, defined by elevated BP, is a most important factor for cardiac disorder, stroke, kidney failure [2]. The increasing prevalence of these conditions underscores the most immediate need for effective management strategies.

Conventional Treatments and Limitations

Medication is the cornerstone of most current treatment regimens for HTN and DM. Insulin and oral hypoglycemic medications (OHAs) are the mainstays of treatment for diabetic mellitus (DM); ACE inhibitors, angiotensin II receptor blockers (ARBs), Ca^{+} channel blockers (CCBs), beta -blockers, and diuretics are a few of these for hypertension (HTN) [3,4].. Notwithstanding their effectiveness, these drugs frequently have serious side effects and might not be appropriate for every patient [5]. Furthermore, continued use of these medications may result in diminished efficacy and drug resistance [6].

Natural Remedies and the Role of T. catappa

The search for alternative and complementary therapies has led to increased interest in natural products with potential therapeutic benefits. Among these, T. catappa has shows as a promising candidate due to its rich phytochemical composition and diverse pharmacological properties. Traditionally, T. catappa have many used in various cultures for its various such as anti-inflammatory, antioxidant, antimicrobial, and hepatoprotective effects [7,8]. Recent studies have highlighted its potential antidiabetic and antihypertensive effects, suggesting that it may offer a novel approach to managing these conditions [9,10].

Objectives

This research aims to comprehensively investigate the antidiabetic and antihypertensive potential of T. catappa by:

1. Identifying and characterizing the bioactive compounds responsible for its therapeutic effects.
2. Elucidating the mechanisms of action underlying its antidiabetic and antihypertensive properties.
3. Evaluating its efficacy by in vitro and in vivo experimental models.

Material with Method

Plant Material with Extraction

Collection with Authentication

T. catappa leaves were collected from mature trees in a controlled environment, ensuring the absence of contamination. Botanist authenticate the plant Material, and a voucher specimen was deposite in the herbal collection for future refereal used [11].

Preparation of Extracts

The gathered leaves underwent washing, drying in the shade, and grinding. As a solvent ethanol is throughout the over all extraction process of the powdered material. Using a rotary evaporator, the extraction procedure included maceration, filtration, and concentration under low pressure. Up to additional analysis, the concentrated extract was kept in storage at 4°C [12].

Phytochemical Analysis

Qualitative Analysis

Preliminaryl screening of the T. catappa extracted product was conducted to identify the visibility or presence of various bioactive compounds, including flavonoids, *tannins, saponins*, *polyphenols*, *and alkaloids*. Standard qualitative methods such as the Ferric chloride test, Lead acetate test, and Froth test were employed [13].

Quantitative Analysis

In Vitro Antidiabetic Assays

Gas chromatography Mass spectrometry (GCMS) and HPLC(high-performance liquid chromatography) were used for the quantitative analysis of the bioactive chemicals that were found. These methods made it possible to precisely quantify polyphenols, flavonoids, and other important substances [14].

α-Amylase Inhibition Assay

To find out if T. catappa extract might block this crucial enzymes, which is involved in the digestion of carbohydrates, was the aim of the α-amylase inhibition assay. The procedure involved incubating the extract with α-amylase and a starch substrate, then measure the releaseing of reducing sugars using the 3,5-dinitrosalicylic acid (DNS) approach [15].

α-Glucosidase Inhibition Assay

The potential of the extract to inhibit α-glucosidase, another important enzyme involved in glucose metabolism, was evaluated using the α-glucosidase inhibition assay. Using a p-nitrophenyl-α-D-glucopyranoside substrate and α-glucosidase, the extract was incubated for the assay [16]. Then, the release of p-nitrophenol was measured spectrophotometrically at 405 nm.

In Vivo Antidiabetic Studies

Animal Models

For the in vivo antidiabetic experiments, male Wistar rats (Rattus norvegicus) weighing 180–200 g were employed. The animals were given a regular pellet food, an endless supply of water, and conventional laboratory conditions with a Tweleve hour light/dark cycle. Institutional Animal Ethics Committee approved each method used in the research [17].

Induction of Diabetes

To induce diabetes in the rats, an intraperitoneal injection of streptozotocin (STZ) at a concentration of 50 mg/kg body weight was administered. Rats identified as diabetics and included in the study were performed those with the fasting or prediet blood glucose levels above than 250 mg/dL following 72 hours of STZ administration [18].

Treatment Protocol

The four groups (n=6 each group) of diabetic rats were split as follows.The four groups (n=6 per group) of diabetic rats were split up as follows:

• Group I: Typical control group (saline was given)
• Group II: saline-treated diabetic control group
• Group III: 100 mg/kg body weight of T. catappa extract was administered to diabetic rats.
• Group IV: 200 mg/kg body

In Vitro Antihypertensive Assays

ACE Inhibition Assay

The purpose of the ACE inhibition assay was to determine whether T. catappa extract could inhibit ACE, an important enzyme that is a parts of the renin-angiotensin-aldosterone system (RAAS). Hippuryl-histidyl-leucine (HHL) substrate and ACE were added to the extract during the assay's incubation period. The release of hippuric acid were then measure spectrophotometrically at 228 nm [20].

In Vivo Antihypertensive Studies

Animal Models

For the in vivo antihypertensive experiments, male Wistar rats were employed. For four weeks, the animals were given a diet high in salt (8% NaCl) in order to develop hypertension. The tail-cuff approach, which is non-invasive, was used to measure blood pressure [21].

Treatment Protocol

The hypertensive rats were divided into four groups (n=6 per group) as follows:

- Group I: Normal control (received saline)

- Group II: Hypertensive control (received saline)
- Group III: Hypertensive rats treated along T. catappa extracts (100 mg/kg body weight)
- Group IV: Hypertensive rats treated along T. catappa extracts (200 mg/kg body weight)

The treatment was administered orally once daily for 28 days. Systolic and diastolic blood pressure was recorded at regular intervals [22].

Results

Phytochemical Composition

Following a phytochemical screening, Flavonoids, Tannins, Saponins, polyphenols, and alkaloids were present in the T. catappa extract. The extract is rich in flavonoids (quercetin, Kaempferol), Polyphenols (Gallic acid, Ellagic acid), and Saponins (asiaticoside), according to quantitative analysis performed using HPLC and GC-MS [23]. Strong anti-inflammatory, antidiabetic, and antioxidant qualities are well-known for these substances [24, 25]

Activity of Antidiabetic

α-Glucosidase α-amylase and α-Amylase Inhibition

The experiments conducted in vitro revealed that T. catappa extract demonstrates notable inhibitory activity in a dose-dependent manner against the enzymes α-amylase and α-glucosidase. Its ability to lower postprandial hyperglycemia was shown by the IC50 values for α-amylase and α-glucosidase inhibition, which were determined to be 75.4 μg/mL and 62.3 μg/mL, respectively [26].

In Vivo Studies

T. catappa extract dramatically lowered blood glucose levels in STZ-induced diabetic rats, according to in vivo research. When compared to the diabetic control group, the diabetic rats treated with T. catappa extract (200 mg/kg) had a 45% decrease in fasting blood glucose levels ($p<0.05$). Furthermore, the histological analysis of pancreatic tissues revealed that the extract restored pancreatic β-cell activity and enhanced insulin sensitivity [27].

Antihypertensive Activity

ACE Inhibition

The ACE inhibition assay demonstrated that T. catappa extract exhibits strong inhibitory activity against ACE, with an IC50 value of 48.7 μg/mL. This suggests that the extract can effectively inhibit the conversion of angiotensin I to angiotensin II, thereby lowering blood pressure [28].

In Vivo Studies

T. catappa extract considerably lowered the systolic and diastolic blood pressure in hypertensive rats, according to in vivo antihypertensive experiments. When compared to the hypertensive control group, the rats treated with T. catappa extract (200 mg/kg) had a 30% reduction in systolic blood pressure and a 25% reduction in diastolic blood pressure ($p<0.05$). Furthermore, as shown by the elevated levels of nitric oxide (NO) and lower levels of malondialdehyde (MDA) in the blood, the extract enhanced endothelial function and decreased oxidative stress [29].

Discussion

Phytochemical Composition and Therapeutic Potential

T. catappa's rich phytochemical makeup is thought to contribute to its medicinal potential. Antioxidant flavonoids, such quercetin and kaempferol, are well-known for their capacity to scavenge free radicals and lower oxidative stress, which is a significant cause of both DM and HTN [30]. Gallic and ellagic acids are two examples of polyphenols with anti-inflammatory and antihyperglycemic qualities., which can improve insulin sensitivity and reduce blood glucose levels [31]. Saponins such as asiaticoside have been reported to exhibit ACE inhibitory activity, thereby contributing to the antihypertensive effects of T. catappa [32].

Mechanisms of Action

Antidiabetic Mechanisms

The antidiabetic effects of T. catappa can be attributed to multiple mechanisms of action. The inhibition of α-amylase and α-glucosidase enzymes reduces the breakdown of carbohydrates into glucose, thereby lowering postprandial blood glucose levels [33]. Additionally, the antioxidant properties of flavonoids and polyphenols help in protecting pancreatic β-cells from oxidative damage, improving insulin secretion and sensitivity [34]. The histopathological examination of pancreatic tissues further supports these findings, indicating that T. catappa extract can restore β-cell function and reduce β-cell apoptosis [35].

Antihypertensive Mechanisms

The antihypertensive effects of T. catappa are primarily mediated through the inhibition of ACE, which reduces the formation of angiotensin II, a potent vasoconstrictor. This leads to vasodilation and a subsequent reduce in blood pressure [36]. The Proper improvement in endothelial functions and the increase in NO levels further contribute to the antihypertensive effects by enhancing vasodilation and reducing vascular resistance [37]. The reduction in oxidative stress, as evidenced by the decreased MDA levels, also plays a crucial role in mitigating hypertension-related damage to the cardiovascular system [38].

Clinical Implications and Future Directions

The results of this investigation demonstrate T. catappa's potential as a natural medicinal agent for the treatment of HTN and DM. T. catappa extract may be developed into a potential treatment for hypertension and blood glucose because of the considerable reductions in these disorders' blood pressure and levels that were seen in the animal models. To validate these results in human subjects and to ascertain the ideal dosage and safety profile of T. catappa extract, additional clinical research is necessary [39].

Conclusion

In conclusion, this study provides comprehensive evidence of the antidiabetic and antihypertensive potential of T. catappa. The rich phytochemical composition of the extract, including flavonoids, polyphenols, and saponins, contributes to its therapeutic effects. The inhibition of key enzyme having involved in carbohydrate metabolism and the RAAS, along with the improvement in oxidative stress and endothelial function, underpin the beneficial effects of T. catappa in managing DM and HTN. Future clinical research and the possible creation of T. catappa-based treatments for hypertension and diabetes are made possible by these discoveries.

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