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REVIEW ARTICLE

Clitoria ternatea (Butterfly Pea) – A Plant with Antioxidant and Antidiabetic Properties

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Abstract

Objectives: *Clitoria ternatea*, commonly known as Butterfly pea is a perennial leguminous plant that has been used in folklore in the treatment of various diseases and is reported to have antioxidant and antidiabetic properties. This review is an effort to compile a detailed account of the antioxidant and antidiabetic activity of the plant and the possible mechanisms behind it. **Method:** The related articles were searched using the databases PubMed, Science Direct, and Google Scholar using terms related to the antioxidant, and antidiabetic activity of *C.ternatea* such as anthocyanins, ternatins, and hypoglycemic activity. **Findings:** Various solvents, namely ethanol, methanol, and chloroform, have been commonly employed for extraction but ethanol extraction consistently demonstrated superior efficiency; however, the choice of a specific solvent should be based on its intended purpose. The assessment of free radical scavenging ability predominantly involved the utilization of the DPPH method. Interestingly, the methanol extract displayed a significantly low IC50 value (95.30 μg/ml), indicating a remarkable antioxidant potential in comparison to the other extracts. The antidiabetic effect was evaluated through the measurement of blood glucose, glycated hemoglobin and insulin levels, and the regeneration of pancreatic cells. In most studies, glibenclamide was employed as the benchmark for comparison. Notably, when diabetic rats were administered the chloroform extract at a dose of 300mg/kg body weight, a remarkable reduction in blood glucose levels was observed, decreasing from 378.33 mg/dl to 136.33 mg/dl after 12 days of treatment. **Novelty:** The novelty of this study lies in its comprehensive approach to understanding the antioxidant and antidiabetic activity of *C. ternatea*. Unlike previous studies that primarily examine the overall pharmacological properties of the plant, this review focuses specifically on compiling a detailed account of how *C. ternatea* and its phytoconstituents combat oxidative stress and contribute to

the management of chronic diseases, particularly diabetes.

Keywords: Antidiabetic Activity; Antioxidant; Bioactive Compounds; Clitoria Ternatea; Oxidative Stress

1 Introduction

Clitoria ternatea (CT) Figure 1 [(1)] belongs to the family Fabaceae and sub-family Papilionaceae.It is a perennial leguminous plant with elliptic and obtuse leaves that grows as a vine or creeper with white to blue flowers and deep roots in tropical regions. The propagation is done through seed and has excellent regrowth after grazing in a short period of time with high yields [(2)]. It produces papilionaceous flowers that are 6-12 cm long with five petals consisting of a standard petal, two wing petals, and two keel petals. It originated in tropical Asia and then spread to China and India [(2)]. *C. ternatea* is drought tolerant, self-pollinates naturally, and has the capability of nitrogen fixation [(3,4)]. The flower contains a variety of natural antioxidants and bioactive compounds, including phenolics, flavonoids, anthocyanins, quercetin glycosides, flavonol glycosides, kaempferol glycosides, terpenoids, myricetin glycosides, tannins, and steroids. These compounds have been extensively studied for their ability to combat oxidative stress. By reducing oxidative stress through the administration of antioxidants from *C. ternatea*, it is hypothesized that the complications associated with diabetes can be effectively managed. The natural antioxidants present in *C. ternatea* can neutralize and scavenge harmful free radicals, thereby alleviating oxidative damage and offering potential therapeutic benefits for diabetes management [(5)].

In the past, the pharmacological properties of *C.ternatea* have been dealt with broadly, but this review exclusively focuses on the antidiabetic and antioxidant properties of the plant. Previous research works have not reviewed the possible mechanisms behind the pharmacological properties, but this review aims to identify the possible relationship between the antioxidant and antidiabetic properties of *C.ternatea* in the management of chronic diseases. Even though the therapeutic effects of the plant are well studied, it is not effectively utilized both medicinally and commercially so in this review, we have summarized the antioxidant and antidiabetic properties of the plant and how it can be potentially used in the food industry as a source of natural food colorants and antioxidants in the development of functional foods.

Fig 1. *Clitoria ternatea.L*

2 Methodology

2.1 Search Strategy

The review was performed by searching the databases PubMed, ScienceDirect, and Google Scholar using terms related to the antioxidant, and antidiabetic activity of *Clitoria ternatea* such as anthocyanins, ternatins, hypoglycemic activity with applying a time restriction of 5 years from 2019 to 2023; however few articles considered for review about the origin and identification of phytoconstituents were dated back to 2000s. The studies involving the applications, and pharmacological properties of *C.ternatea* were included in this review.

2.2 Selection Criteria

Studies involving the application and pharmacological properties focusing on the antioxidant and antidiabetic activity of *C.ternatea* were included in this review. Only clinical trials and research articles were included in the study. In this review, a comprehensive analysis was conducted by reviewing a total of 3 articles that focused on pharmacological activity and 6 research articles to showcase the antioxidant activity. Furthermore, the review incorporated findings from 5 clinical studies specifically focused on demonstrating the antidiabetic activity of *C.ternatea*. The inclusion of clinical trials provides valuable insights into the effectiveness of this plant in managing diabetes, while the analysis of antioxidant activity sheds light on its potential to combat oxidative stress. There are also certain review article findings included in this review to compile data regarding the phytoconstituents and to conclude the findings that were observed.

2.3 Traditional properties and uses

Clitoria ternatea, commonly known as Butterfly pea, blue pea vine, or Pigeon wings, is a plant that holds cultural significance and is referred to by different names in various languages. In Sanskrit, it is known as Aparajita Saukarnika, Shwetanama, or Vishnu-Kranta. In Hindi and Oriya, it is called Aparajita or Aparajit. In Tamil, it goes by the name Kakkanam or Kokkattan, while in Malayalam, it is known as Aral or Shankapuspam. These names reflect the diverse cultural and linguistic contexts in which this plant is found. Taxonomically, *Clitoria ternatea* belongs to the Plantae kingdom and falls under the Angiosperms phylum. Within the order Fabales, it is classified under the family Fabaceae, also known as the pea or legume family. It is categorized under the genus Clitoria and specifically identified as the species *C. ternatea* within this genus. The flowers of this plant resemble the shape of the human female Clitoris hence the Latin name of the genus "Clitoria" belongs to Clitoris and "Ternatea" name of the species comes from Ternate, an Eastern Indonesian Island. As the flowers resemble conch shells it is called Shankpushpi in Sanskrit and is used as a brain tonic drug (Medhya) in the treatment of mental illness in Ayurveda.[(5)]

Different parts of this plant have been used in folklore in the treatment of bronchitis, diuretics, rheumatism, infertility, ascites, liver problems, and diabetes mellitus. It is also used as an ornamental plant because of its vivid, blue-colored flowers. The young flowers, shoots, and leaves are consumed in Kerala and the Philippines.[(4)] The medicinal properties are validated and reported to have antioxidant, antidiabetic, and hepatoprotective properties.The water extract of flowers has shown anti-proliferative properties inhibiting cancer cell lines. The juice of flowers has been traditionally used to treat skin diseases and insect bites[(5)]. The flower is used as natural food colorant due to its blue hue and has numerous phytochemicals like tannins, glycosides, saponins, alkaloids, triterpenoids, anthraquinones, flavonoids, volatile oils, and polyphenols that are beneficial for health. Sero-XR, the first *C.ternatea*-based insecticide is used on macadamia nut and cotton crops for insect control. Butelase-1 enzyme isolated from *C.ternatea* pods is gaining importance as a biotechnological tool for peptide ligation and cyclization[(6)].

2.4 Phytoconstituents of *Clitoria ternatea*

Initially, Kulshreshtha and Khare reported that *C.ternatea* seed contains flavanol glycosides, cinnamic acid, and phenolic aglycones. Later Saito isolated five flavanols from *C.ternatea* namely kaempferol, kaempferol 3-glucoside kaempferol 3-robinobioside-7-rhamnoside, quercetin,and quercetin 3-glucoside. In addition, he reported six acylated anthocyanins from blue flowers which were derivates of delphinidin 3,30,50-triglucoside and termed these as ternatins which were explored in subsequent studies.

The identified flavonol glycosides were found in all *C.ternatea* lines bearing blue, white, and mauve floral colors. The novel anthocyanin of *C.ternatea* renders that vivid blue color to the flowers. The presence of ternatins Figure 2[(7)] with other secondary metabolites in the plant makes it an ideal source of natural additives that enhance consumer products' nutritive value and appearance.The structure of ternatin A1, the largest and most stable blue anthocyanin in a neutral solution, was determined in 1989 by Terrahara[(6)].

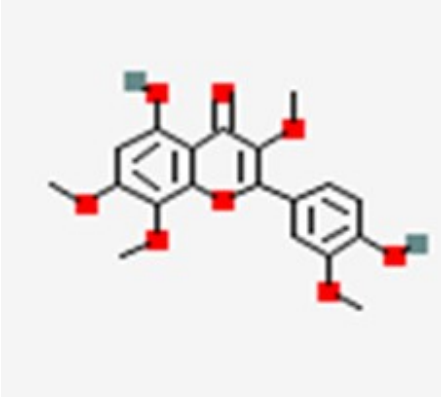

Fig 2. Ternatin

The structures of ternatins A2, B1, B2, D1, and D2 were determined in subsequent years. Several novel ternatins – A3, B3, B4, C1, C5, D3 and preternatins A3 and C4 were later isolated. In 2003, Kazuma investigated the anthocyanin content in different floral colors of *C.ternatea* and reported that white flowers don't contain any anthocyanins. Phytochemical screening of the roots revealed the presence of ternatins, taraxerol, taraxerone, saponins, flavonoids, alkaloids, carbohydrates, resins, tannins, starch, and proteins.Novel norneolignans, clitorienolactones A-C were also isolated from the roots in 2016. There are other types of flavonoids in *C.ternatea* floral extracts such as rutin (flavone), epicatechin (flavanol), and other polyphenolic acids (gallic acid, protocatechuic acid, and chlorogenic acid).In the family of Fabaceae, only *C.ternatea* contains the proteinaceous compound cyclotide [6].

2.5 Applications of *Clitoria ternatea* in Medicine

Various animal studies have reported that *C.ternatea* extracts show nootropic, antioxidant, antilipidemic, antipyretic, anti-inflammatory, and wound-healing properties. [Table1] The drug Shankhapushpi made from seeds and roots of CT is used as a tonic for nerves. The stem, root, and flowers are also used in the treatment of snakebites and scorpion stings. [4] The extracts of leaves and roots have shown anti-inflammatory and analgesic properties [8]. Further studies have shown that treatment with CT root extract resulted in increased acetylcholine, a neurotransmitter that facilitates memory and learning. CT root extract promotes neurogenesis in the amygdala and stimulates the release of neuromodulators that enhances learning and memory [8].

In 2008, ternatins D1 isolated from petals was studied for its in vitro platelet aggregation inhibitory activity in rabbits and reported significant inhibition of collagen and adenosine diphosphate (ADP) induced aggregation of platelets [4]. The 2004 study by Daisy reported that treatment with aqueous extracts of CT leaf and flower in alloxan-induced diabetic rats for 60 days significantly increased the count of white blood cells, red blood cells, T lymphocytes, and B lymphocytes. It was also found that these extracts have immunomodulatory effects that strengthen the immune system [6]. These are attributed to the presence of bioactive compounds like flavonols and anthocyanins that could work synergistically.

2.6 Antioxidant activity

2.6.1 Oxidative Stress and Antioxidant Defence System

Oxidative stress is the excess formation and or insufficient removal of reactive oxygen species (ROS) and Reactive nitrogen species (RNS). ROS are chemically active oxygen-containing molecules generated in the human body. They are the by-products of oxygen metabolism in aerobic organisms. The major ROS are superoxide, hydroxyl radical, singlet radical, hydroperoxyl radicals, nitric oxide, and peroxynitrite [9].

It is well-established that oxidative stress is an important causative factor in chronic degenerative diseases. ROS are p roduced under physiological conditions and are involved in signaling molecules and defense mechanisms like in phagocytosis, and stress-induced vasorelaxation but excess production has detrimental effects on the human body like damage to lipids, proteins, and DNA. There are antioxidant enzymes like Glutathione peroxidase, superoxide dismutase, and glutathione reductase that limit the harmful effects of ROS. Non-enzymatic antioxidants like polyphenols, melatonin, ascorbate, retinol, and ceruloplasmin are also part of the defense system against ROS. Antioxidants act as free radical scavengers and reduce the harmful effects of ROS [9].

Table 1. Few studies demonstrating the pharmacological activity of *Clitoria ternatea*

Treatment	Experimental Animal	Results	
Different extracts at varied dose levels were used to evaluate the analgesic and anti-inflammatory activity of *Clitoria ternatea* using the carrageenan-induced paw edema and tail flick method.	Rats	Ethanol and petroleum ether extract (400mg/kg) showed maximum inhibition in analgesic activity and in the treatment of inflammatory conditions.	[10]
Medhya Rasayana was prepared with the whole plant of *Clitoria ternatea* and jaggery in 1:1 ratio and was then mixed with animal feed and fed to animals for a period of 90 days.	Male albino Wistar rats	This resulted in a significant decrease in autophagy in the brain of the treated rats.	[11]
The ethanolic extract of flowers was evaluated for its anti-allergy and anti-tussive potential.	Goat tracheal chain and isolated guinea pig ileum	The flowers attenuated histamine-induced contraction in experimental animals.	[4]

2.6.2 Antioxidant activity of Clitoria ternatea

Antioxidants of butterfly pea-like phenolics, flavonoids, anthocyanins, quercetin glycosides, flavonol glycosides, kaempferol glycosides, terpenoids, myricetin glycosides, tannins, and steroids have been studied to combat oxidative stress. The petals of *C. ternatea* have been recognized to possess significant antioxidant activity compared to other parts of the plant[8]. Since oxidative radicals are detrimental to the body due to their reactivities toward biomolecules and associations with various diseases, *C.ternatea* flower, which is rich in several natural antioxidants and bioactive compounds might thus provide protection against oxidative damage.

The in vitro antioxidant capacity of *Clitoria ternatea* extracts was assessed using various assays, and the obtained results were compared to standard antioxidants such as butylated hydroxytoluene (BHT), ascorbic acid, and rutin. The findings revealed significant antioxidant activity in the *Clitoria ternatea* extracts. One recent study reported total phenolic content and anthocyanins in spray-dried aqueous extract of *C.ternatea* flowers as 53.08 $\pm$ 0.08 mg gallic acid equivalents/ g extract and 1.08 $\pm$ 0.12 mg delphinidin-3-glucoside equivalents/g extract respectively. Flavonoids of *Clitoria ternatea* including anthocyanins, scavenge free radicals and prevent oxidative stress and inflammation[8].

Numerous studies have examined the antioxidant activity of *C. ternatea* flowers using various antioxidant assays, including the evaluation of 2,2-diphenyl-1-picrylhydrazyl radical (DPPH) scavenging, ferric reducing antioxidant power (FRAP), hydroxyl radical scavenging activity (HRSA), hydrogen peroxide scavenging, oxygen radical absorbance capacity (ORAC), superoxide radical scavenging activity (SRSA), ferrous ion chelating power, 2,2'-azino-bis(3-ethylbenzthiazoline-6-sulphonic acid) (ABTS) radical scavenging, and Cu^{2+} reducing power assays[12] (Table 2)

The extraction procedure of phytochemicals from plant materials plays a crucial role in obtaining high yields. Different extraction methods are available, and it is essential to identify and select the optimal parameters to maximize extraction efficiency and enhance the yield of phytochemicals. Before the extraction process, it is common practice to decrease the size of plant materials to enhance the surface area for better mixing with the solvent. In the case of studies on *C. ternatea* flowers, various approaches have been employed. Some studies utilized air-dried or oven-dried fresh flowers, while others used dried flowers that were ground or powdered. Additionally, certain studies employed fresh flowers that were cut into smaller pieces, washed, and stored in a freezer at -25 °C for up to one month before extraction. Alternatively, freeze-drying was performed on the flowers followed by grinding prior to extraction.

In a study conducted by Ludin et al. (2018), the extraction efficiency of anthocyanins was investigated using solvents with varying polarities. It was observed that the ethanol extract exhibited the highest efficiency in extracting anthocyanins, while the ethyl ether extract showed the lowest efficiency. The study concluded that solvents with higher polarity, such as ethanol, tend to effectively extract polar compounds like anthocyanins. By investigation, it was determined that the extraction temperature for anthocyanin extraction increases with rising temperatures, and the optimal temperature for this extraction process was found to be 70 °C[21].

To evaluate the free radical scavenging ability using the stable radical DPPH (1,1-diphenyl-2-picrylhydrazyl), a study was conducted by Rajamanickam where various extracts of *Clitoria ternatea* flowers were tested, with L-Ascorbic acid employed as the positive control. The dried flowers were subjected to extraction using methanol, chloroform, and ethyl acetate. The methanol extract exhibited significant antioxidant activity, as indicated by its low IC50 value (95.30 μg/ml), which was comparable to the standard antioxidant L-ascorbic acid.[1] In a randomized crossover study involving healthy men, the acute ingestion of *C. ternatea* flower extract or beverage was observed to result in increased plasma antioxidant capacity. Furthermore, when

Table 2. Few studies demonstrating the antioxidant activity of *Clitoria ternatea*

Plant part	Extract	Antioxidant assay	Standard	Results	
Air-dried blue flowers	1.Chloroform 2. Ethyl acetate 3. Methanol	DPPH (IC50 μg/ml)	L-Ascorbic acid	1. 132.50 $\pm$ 0.06 2. 107.42 $\pm$ 0.02 3. 95.30 $\pm$ 0.10	[12]
Shade-dried blue flowers	Ethanolic extract	1. DPPH (% inhibition) 2. FRAP (% reducing power) 3.H_2O_2 radical scavenging activity (%)	L-Ascorbic acid	1. 62$\pm$4.30 2. 75$\pm$5.25 3. 88.9$\pm$6.22	[13]
Blue flowers	Water extract	1. DPPH radical scavenging 2. ABTS radical scavenging	Trolox standard	1.IC50=195.5 μg/mL 2.IC50=42.9 μg/mL	[14]
Blue flowers	1. Water extract 2. Methanol extract 3. Water methanol (1:1 ratio)	DPPH Radical Scavenging	Trolox standard	1. 11.7 mM trolox equivalent/g extract 2.6.99 mM trolox equivalent/g extract 3.12.2 mM trolox equivalent/g extract	[15]
Fresh petals of blue flowers	Water extract	1. DPPH radical scavenging 2. FRAP Assay	L-Ascorbic acid	1. IC50 1.18 mg/mL 2. 19.8 mg of gallic acid equivalent/g of extract	[16]
Dried ground petals of blue flowers	Water extract	ABTS Assay	Trolox standard	467.04 mmol Trolox equivalent/g	[17]

Table 3. Application of the antioxidant activity of *Clitoria ternatea*

Product	Antioxidant activity	
Functional beverage using dried blue flowers	DPPH radical scavenging activity – IC50 –247.6 mL/mL ABTS radical scavenging activity – IC50 –35.8 mL/mL FRAP – 14.9 mg Trolox equivalent/L ORAC – 122.2 mg Trolox equivalent/L	[18]
Functional drink powder	Powder showing 35–40% scavenging in DPPH radical scavenging activity	[19]
Yogurt (liquid skim milk, UHT milk, pasteurized milk, UHT milk with skim powder, and pasteurized milk with skim powder)	69.3–437.04 ppm BHT equivalent in DPPH radical scavenging activity	[20]

consumed in combination with sucrose, the effect was found to be even more pronounced [2].

Numerous studies have been carried out, and the identification of a singular solvent as the most efficient one is impractical due to several factors, including the processing technique employed for plant material, the specific plant part utilized, and variables like extraction duration and temperature. Consequently, the selection of a solvent should be contingent upon its intended purpose. It is advisable to avoid the use of hazardous organic solvents, particularly when extracting anthocyanins for food purposes, as highlighted in studies by Chemat et al. [22] Most of the studies have used ethanol, methanol, and chloroform for the extraction however, it is worth noting that the FDA (2018) classifies methanol as a class 2 solvent with inherent toxicity, and ethanol as a class 3 solvent that should be limited according to good manufacturing practices (GMP) and other quality-based requirements. In this context, distilled water emerges as the preferred solvent for extracting anthocyanins for food applications owing to its appropriateness and emphasis on safety.

2.7 Antidiabetic activity

2.7.1 Oxidative Stress and Diabetes

Hyperglycemia increases the generation of ROS because glucose undergoes autoxidation to generate • OH radicals and it also enhances • O2 production through the polyol pathway. Studies have reported that hyperglycemia-induced generation of • O2 is the initial trigger of the vicious cycle of oxidative stress in diabetes.These free radicals initiate the peroxidation of lipids leading

to protein glycation, enzyme inactivation, and change in the structure and functions of membranes contributing to long-term complications of diabetes[23]. Several studies have reported that hyperglycemia-induced free radical generation leads to the development and progression of diabetes. Therefore, reducing oxidative stress through treatment with antioxidants may be useful in managing diabetes complications.

2.7.2 Antidiabetic activity of Clitoria ternatea

Postprandial hyperglycemia and hyperinsulinemia result in excessive generation of free radicals andstudies have reported that postprandial hyperglycemia can be controlled by delaying carbohydrate digestion and absorption by inhibiting pancreatic α-amylase and intestinal α-glucosidase[23]. Research findings have indicated that extracts derived from *Clitoria ternatea* have shown potential in regulating the biochemical markers associated with diabetes mellitus. Plant bioactive compounds like anthocyanins and polyphenols exert antidiabetic activity by inhibiting pancreatic α-amylase and α-glucosidase activity.It is suggested that the phenolic compounds present in *C.ternatea* might work in the same way and hence result in the delay of postprandial glucose[24].

In a 2015 study investigating the antidiabetic potential of *C.ternatea* (CT) plant, diabetic rats were administered various extracts of CT flowers at a dosage of 300 mg/kg. The results indicated notable effects on blood glucose levels compared to the diabetic control group. Specifically, the chloroform extract demonstrated a significant reduction from 378.33 mg/dl to 136.33 mg/dl, the ethyl acetate extract lowered blood glucose levels from 385.67 mg/dl to 169.67 mg/dl, and the methanol extract decreased levels from 382.43 mg/dl to 171.42 mg/dl. Furthermore, a daily treatment regimen with all the extracts over 12 days resulted in a dose-dependent decrease in blood glucose levels, with the chloroform extract displaying the most significant reduction[12].

A study conducted in 2018 explored the effects of CT ethanolic leaf extract on rats with diabetes. The diabetic rats received a daily dose of 400 mg/kg body weight for 28 days. The results demonstrated significant reductions in blood glucose, insulin, glycosylated hemoglobin, urea, and creatinine levels in the treated rats compared to the diabetic control group. Furthermore, the treated rats exhibited lower levels of liver enzymes, including serum glutamate oxalate transaminase, serum glutamate pyruvate transaminase, lactate dehydrogenase, and alkaline phosphatase, which were comparable to those observed in the normal control rats[25]. According to the study, conducted by Viena et al., the control group treated with aquabidest and Glimepiride exhibited a lower number of pancreatic beta cells (8.84 ± 5.32 cells/field of view) compared to the treatment group receiving Butterfly pea flower extracts and Glimepiride (19.54 ± 8.11 cells/field of view). Furthermore, when examining HbA1c levels, the control group showed higher levels of HbA1c (35.78 ± 8.96 ng/mL) compared to the treatment group (28.91 ± 8.73 ng/mL). This indicates that the oral ethanol extract of CT can increase the number of pancreatic beta cells can reduce the levels of glycated hemoglobin (HbA1c) in male Wistar rats with diabetes mellitus[26].

In a recent study, diabetic dyslipidemic rats were subjected to treatment with various doses of *C.ternatea* extract (CTE) (200 mg/kg BW, 400 mg/kg BW, and 800 mg/kg BW), along with glibenclamide at a dosage of 0.45 mg/kg BW. After a duration of 28 days, the results revealed that CTE at a dosage of 400 mg/kg BW exhibited the highest effectiveness in reducing glucose levels and increasing insulin levels. This dosage demonstrated the most pronounced impact among all the treatment groups, suggesting its potential as an effective intervention for managing diabetes in conjunction with dyslipidemia[27].

Various dosages of CTE extracts were administered to diabetic rats to evaluate the impact of CTE on serum oral glucose tolerance test (OGTT). The diabetic rat model exhibited an initial increase in glucose levels during the 0–4-hour period, followed by a decline at the 6-hour mark. However, the administration of CTE treatment proved to be effective in reducing blood glucose in diabetic rats. It is worth noting that an immediate reduction in blood glucose levels was not observed at the 0-hour mark after CTE treatment. Among the different CTE treatment groups, the 800 mg/kg body weight (BW) dosage emerged as the most effective in decreasing OGTT. However, it was found that CTE at a dosage of 400 mg/kg BW exhibited the highest effectiveness in reducing glucose levels and increasing insulin levels[28].

Delphinidin-3-glucoside and kaempferol present in *C.ternatea* have shown inhibitory effects against pancreatic α-amylase and α-glucosidase activity in vitro. It is also reported that Kaempferol reduces fasting blood glucose, and HbA1c, and increases insulin resistance. Quercitin is shown to decrease glucose absorption by inhibiting GLUT2[24]. Clinical research involving 15 healthy men showed that ingestion of *C.ternatea* extract with sucrose resulted in improved antioxidant status and reduced postprandial glucose and insulin concentration[2].

The possible hypoglycemic mechanism of *C.ternatea* extracts might be stimulation of insulin secretion by pancreatic beta cells or increased transport of blood glucose to peripheral tissues. This review aimed to assess the antioxidant and antidiabetic properties of *Clitoria ternatea*. Numerous research studies have established a connection between antioxidants, oxidative stress, and diabetes mellitus. Chronic diseases such as diabetes are characterized by an increase in oxidative stress, which can lead to cellular damage and contribute to the progression of the disease. Antioxidants play a critical role in combating oxidative

Table 4. Few animal studies on the antidiabetic activity of *Clitoria ternatea*

Plant Part used	Extraction method	Animal used	Duration	Experimental groups	Standard drug used	Results	
Blue flowers	Flower materials were shade-dried and extracted 3times with 95% methanol, ethanol, and Chloroform.	Male albino rats of wistar strain	12days	Control groups: Normal control, Alloxan-induced diabetic control, Standard treated with glibenclamide Treatment groups: 300mg/kg Chloroform, ethyl acetate, and methanol extract	Glibenclamide	Decrease in blood glucose levels in treatment groups: Glibenclamide: 374.33mg/dl to 152.00mg/dl Chloroform extract: 378.33 mg / dI to 136.33 mg / dI Ethyl acetate extract: 385.67 mg / dl to 169.67 mg / dI Methanolic Extract:382.43mg/dl to 171.42mg/dl	(12)
Leaves	Shade-dried leaves were extracted with ethanol	Male adult albino rats of wistar strain	28days	Control groups: Normal control, Streptozotocin induced diabetic control, Standard treated with Glibenclamide (600 μg/kg body weight) Treatment groups: 200mg/kg and 400mg/kg body weight ethanolic leaf extracts	Glibenclamide	There was decrease in blood glucose,glycated hemoglobin and increase in serum insulin in extract treated rats and the decrease was dose dependent .	(25)
Blue flowers	Ethanolic extract	Male Wistar rats	60days	Control group: Glimepiride 0.036 mg/200mg of body weight. Treatment group: 80mg/200mg body weight ethanolic flower extract.	Glimepiride	The average number of pancreatic beta cells in the treatment group was significantly increased (19,54±8,11 cell/field of view) compared to the control group (8,84±5,32 cell/field of view). The average HbA1c% in the treatment group (28,91±8,73 ng/mL) was lower than the control group (35,78±8,96 ng/mL).	(26)
Blue flowers	Ethanol extraction	Male rats of Sprague Dawley species	28days	CTE (200, 400, 800 mg/kg BW), Glibenclamide 0.45 mg/kg of bodyweight	Glibenclamide	The CTE decreased glucose levels and increased insulin levels of DM rats. 400 mg/kg BW CTE extract was found to be more effective.	(27)
Flowers	Ethanol extraction	Mice	7days	Control Group: Normal control, Positive control Treatment Group: 200mg/kg,400mg/kg,600mg/kg body weight CTE extract	Glibenclamide	CTE at a dose of 400 mg had a significant decreasing effect on reducing blood glucose levels (31.2 mg/dl) in alloxan-induced rats.	(28)

stress by neutralizing free radicals and safeguarding the body from oxidative damage. *Clitoria ternatea* contains numerous phytoconstituents such as phenolics, flavonoids, anthocyanins, quercetin glycosides, flavonol glycosides, kaempferol glycosides, terpenoids, myristetin glycosides, tannins, and steroids which possess impressive antioxidant properties that can effectively counteract oxidative stress. In relation to diabetes mellitus, these phytochemicals have shown promising potential in influencing glycemia through multiple mechanisms. Firstly, they inhibit pancreatic alpha-amylase and α glucosidase, which are responsible for carbohydrate digestion and glucose absorption in the gut.By inhibiting these enzymes, these phytoconstituents delay the breakdown of carbohydrates and hence reduces postprandial blood sugar levels.They also improve insulin sensitivity and hence help improve glucose uptake by the cells and promote better glycemic control. Additionally, studies have reported that the extracts stimulate insulin secretion from pancreatic beta cells. By increasing insulin secretion, the compounds may contribute to better glucose regulation. In summary, the antioxidant properties of Clitoria ternatea's phytoconstituents help combat oxidative stress, which is implicated in the development and progression of diabetes. The plant's compounds can influence glycemia through mechanisms such as inhibiting carbohydrate-digesting enzymes, improving insulin sensitivity, and stimulating insulin secretion. Research studies have validated many medicinal properties of this plant, but it is essential to isolate individual compounds from the plant and study their activity to further exploit them in the pharmaceutical industry. These findings suggest that *Clitoria ternatea* may hold promise as a natural remedy for managing diabetes and its associated complications. However, further research is needed to fully understand its therapeutic potential and establish appropriate dosages for effective use.

3 Conclusion

This review provides insight into the antioxidant and antidiabetic properties of *C.ternatea* and its phytoconstituents. Various research studies have reported this plant's antioxidant, antidiabetic diuretic, and hepatoprotective properties which are attributed to the presence of phenolic compounds like anthocyanins, ternatins, and quercitin glycosides that work synergistically; hence the flowers can be a potential additive in the development of functional foods and pharmaceutical drugs. Studies have addressed the importance of antioxidant-rich foods in the management of chronic diseases like Diabetes mellitus, therefore the development of functional foods using *C.ternatea* can be considered a useful strategy for the long-term and effective management of diabetic individuals. The plant is also easy to grow and since Food and Drug Administration has approved an aqueous extract of *C.ternatea* petals as a colour additive it can be utilized as a natural color additive and can be incorporated in the formulation of functional foods. Studies have claimed *C.ternatea* is safe for consumption and showed no sign of acute toxicity. Future studies can explore the synergistic effects of *C.ternatea*'s phytoconstituents, such as phenolic compounds including anthocyanins, ternatins, and quercitin glycosides, to determine the optimal combination for maximum antioxidant and antidiabetic benefits. Additionally, investigating the long-term effects of incorporating *C.ternatea* into functional foods for diabetic individuals would provide valuable data on its efficacy as a management strategy. Further studies can focus on optimizing extraction methods to enhance the stability and bioavailability of the phytochemicals, ensuring their effectiveness in product commercialization. To broaden the scope of research, future studies can also investigate the interaction between *C.ternatea* and other high glycemic index ingredients to assess how it modulates the glycemic response. Understanding these interactions can contribute to the development of innovative dietary approaches for managing blood glucose levels effectively.

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