Records of Natural Products

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REVIEW ARTICLE

# Botany, phytochemistry, pharmacology and application of *Clitoria ternatea* L.: a review

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**ABSTRACT:** *Clitoria ternatea* L. (Fabaceae) is a leguminous plant with a long history of medicinal use and multifaceted applications, widely distributed throughout the tropical and subtropical regions of Asia, Africa, the Americas, and Oceania. In traditional medicine, particularly within the Ayurvedic system, *C. ternatea* has been employed to treat various ailments such as diabetes, cognitive impairment, and respiratory disorders. With advancing research into its chemical composition and pharmacological activity, *C. ternatea* has been found to possess a rich array of bioactive constituents, including flavonoids, anthocyanins, lignans, and triterpenoids. It exhibits diverse pharmacological effects such as hypoglycemic and hypolipidemic properties, memory enhancement, antibacterial and insecticidal action, anti-inflammatory effects, cough suppression, and antitumor activity. Moreover, *C. ternatea* demonstrates broad application prospects across agriculture, cosmetics, food additives, and pesticides. This article aims to provide a systematic review of the plant's botanical characteristics, chemical constituents, pharmacological activities, and practical applications, thereby offering a reference framework for subsequent in-depth research and comprehensive development.

**Keywords:** *Clitoria ternatea* L, Fabaceae, phytochemistry, pharmacology, applications

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## 1 Introduction

*Clitoria ternatea* L., commonly known as butterfly pea, is a perennial herbaceous plant belonging to the genus *Clitoria* within the Fabaceae family. It is widely distributed throughout tropical and subtropical regions. The roots, leaves, flowers, and seeds of *C. ternatea* possess medicinal value (Mukherjee et al., 2007). Commonly known as Shankhpushpi in India, it is one of the potential herbs in Ayurvedic medicine. *C. ternatea* is widely employed in traditional medicine, particularly as a brain supplement to enhance memory and cognitive function (Mukherjee et al., 2008). In Thailand and Malaysia, its flowers are commonly used for food coloring and in tea preparations (Neda et al., 2013). In southern China, *C. ternatea* is cultivated both as an ornamental plant and for medicinal purposes. To date, the chemical composition and pharmacological activity of *C. ternatea* have been extensively studied. 57 compounds have been isolated and identified from this plant, primarily consisting of flavanols and anthocyanins. Modern pharmacological research indicates that *C. ternatea* possesses multiple bioactive properties, including hypoglycemic and hypolipidemic effects, memory enhancement, antibacterial, anti-inflammatory, antitumor, and antioxidant activities (Oguis et al., 2019). It demonstrates broad application prospects across various fields. This article aims to systematically update the chemical constituents and pharmacological activities of *C. ternatea*, with a particular focus on research findings from the past decade. By concentrating on recent advances, this review seeks to bridge existing knowledge gaps and reveal novel insights into its phytochemical composition and mechanisms of action. Through the aforementioned analysis, this review not only updates research on *Clitoria ternatea* but also provides a robust reference framework for emerging research directions. Its ultimate objective lies in advancing the scientific research and development of these traditional medicinal plants, thereby promoting their deeper modernisation and diversified value-added development.

## 2 Search Strategy

In this paper, a comprehensive research and analysis of previously published literature was carried out to investigate the botany, phytochemistry, pharmacology, applications of the *C. ternatea*. All literature on *C. ternatea* was collected by

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using databases such as Medline PubMed, Science Direct, Web of Science, Google Scholar and CNKI. The keywords searched included: *Clitoria ternatea*, butterfly pea, chemical composition of *Clitoria ternatea*, applications of *Clitoria ternatea*. Some of the analysed studies were obtained by manually searching articles in the reference lists of the included studies. Chemical structures were drawn with Chem Draw Professional 20.0 software.

## 3 Botany, Description and Distribution

*C. ternatea* is a well-known Ayurvedic herb used to treat a variety of ailments. *C. ternatea* is primarily distributed in the tropical and subtropical regions of Asia, Africa, Oceania, and the Americas, including India, Thailand, Malaysia, central and southern China, southeastern China, Madagascar, Kenya, Brazil, Mexico, and Australia (Figure 1A) (GBIF, 2025). Due to its ornamental and agricultural value, *C. ternatea* has been introduced to other tropical and subtropical regions. Highly adaptable, it is commonly found in low-altitude open areas, farmland, and gardens.

According to the Flora of China, *C. ternatea* is a climbing herbaceous vine (Figure 1B). The stems and branches are slender and weak, covered with deciduous, appressed, short, soft hairs. The length of the leaves is 2.5–5 cm. The stipules are linear, small, and 2–5 mm long. The leaflets are 5–7 in number, thinly papery or nearly membranous, broadly elliptic or sometimes nearly ovate, 2.5–5 cm long, and 1.5–3.5 cm wide. The leaflets are usually provided with minute apical points, and both surfaces are sparsely covered with appressed short soft hairs or occasionally glabrous. The flowers are large, borne singly in the axils, with two lanceolate bracts. The bracts are membranous, nearly circular, green in color, 5–8 mm in diameter, and bear conspicuous reticulate veins. The calyx is membranous, 1.5–2 cm long, and 5-lobed, with lanceolate lobes. The corolla is blue, pink, or white (Figure 1C, D), up to 5.5 centimeters long, with a broad obovate standard petal approximately 3 centimeters in diameter, bearing a pale white or orange-yellow central band. The stamens are diadelphous, and the ovary is pubescent. The pod is 5–11 cm long, approximately 1 cm wide, flattened, with a long beak, and contains 6–10 seeds. The seeds are oblong, approximately 6 millimeters long and 4 millimeters wide, black in color, and possess a conspicuous aril (Wu et al., 2007).

## 4 Phytochemistry

Up to now, 65 chemical compounds have been isolated and identified from *C. ternatea*. The main types include flavonoids, as well as small amounts of lignans, triterpenoids, steroids, and fatty acid compounds. Flavonoids are the main active ingredients in *C. ternatea*. Furthermore, there are significant differences in chemical composition between different parts of the plant.

### 4.1 Flavonoids

Flavonoids are the main chemical components of *C. ternatea*. To date, 39 flavonoids have been identified from *C. ternatea*. These compounds include flavanols (**1**~**18**) and anthocyanins (**19**~**39**). The flavonoid compounds in *C. ternatea* flowers predominantly exist as glycosides, whilst the anthocyanins are acetylated anthocyanins based on anthocyanidins. The

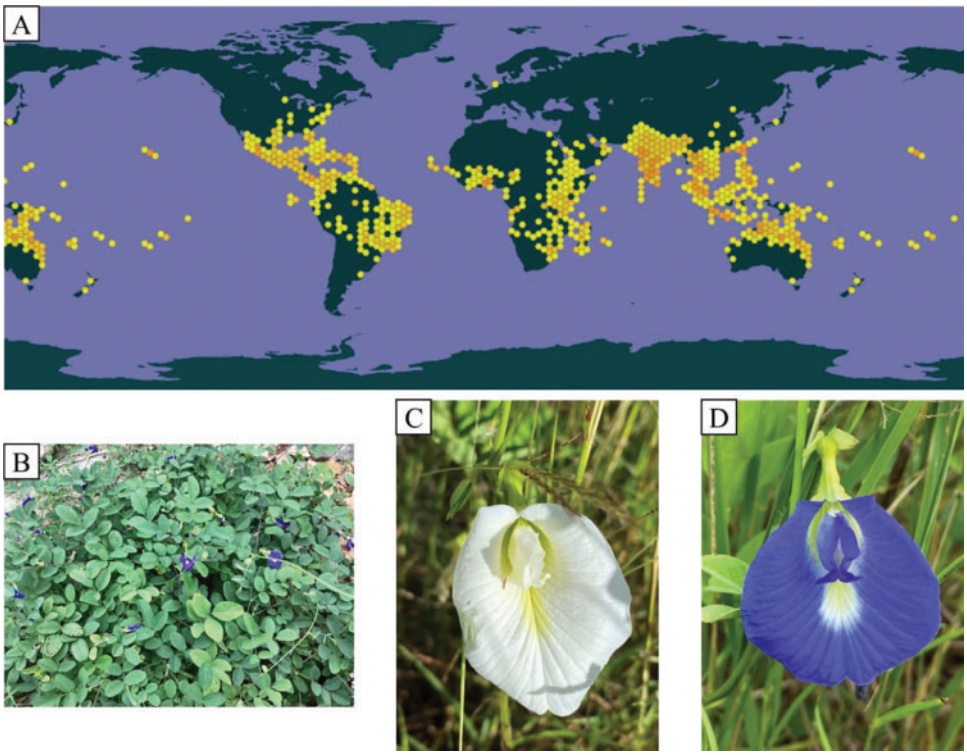


**Figure 1.** Morphology and distribution of *C. ternatea*


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**Table 1.** Flavonoid compounds from *C. ternatea*

| No. | Compounds | Parts | Ref. |
|---|---|---|---|
| 1 | Kaempferol | Flowers | Saito et al. (1985) |
| 2 | Kaempferol-3-robinobioside-7-rhamnoside | Flowers | Saito et al. (1985) |
| 3 | Kaempferol-3-neohesperidoside | Flowers, Leaves | Kazuma et al. (2003a), Morita et al. (1977) |
| 4 | Kaempferol 3-*O*-(2″-*O*-*α*-rhamnosyl-6″-*O*-malonyl)-*β*-glucoside | Flowers | Kazuma et al. (2003a) |
| 5 | Kaempferol 3-2$^{G}$-rhamnosylrutinoside | Flowers | Kazuma et al. (2003a) |
| 6 | Kaempferol 3-rutinoside | Flowers, Leaves | Kazuma et al. (2003a), Morita et al. (1977) |
| 7 | Kaempferol 3-glucoside | Flowers, Leaves | Kazuma et al. (2003a), Morita et al. (1977) |
| 8 | Quercetin | Flowers | Saito et al. (1985) |
| 9 | Quercetin 3-*O*-(2″-*O*-*α*-rhamnosyl-6″-*O*-malonyl)-*β*-glucoside | Flowers | Kazuma et al. (2003a) |
| 10 | Quercetin 3-2$^{G}$-rhamnosylrutinoside | Flowers | Kazuma et al. (2003a) |
| 11 | Quercetin 3-neohesperidoside | Flowers | Kazuma et al. (2003a) |
| 12 | Quercetin 3-rutinoside | Flowers | Kazuma et al. (2003a) |
| 13 | Quercetin 3-glucoside | Flowers | Saito et al. (1985), Kazuma et al. (2003a) |
| 14 | Myricetin 3-*O*-(2″,6″-di-*O*-*α*-rhamnosyl)-*β*-glucoside | Flowers | Kazuma et al. (2003a) |
| 15 | Myricetin 3-neohesperidoside | Flowers | Kazuma et al. (2003a) |
| 16 | Myricetin 3-rutinoside | Flowers | Kazuma et al. (2003a) |
| 17 | Myricetin 3-glucoside | Flowers | Kazuma et al. (2003a) |
| 18 | 3,5,4′-trihydroxy-7-methoxyflavonol-5-*O*-*α*-*L*-xylopyranosyl-(1→3)-*O*-*β*-*D*-galactopyranosyl-(1→6)-*O*-*β*-*D*-glucopyranoside | Seeds | Yadava & Verma (2003) |
| 19 | Ternatins A1 | Flowers | Terahara et al. (1990) |
| 20 | Ternatins A2 | Flowers | Terahara et al. (1990) |
| 21 | Ternatins A3 | Flowers | Terahara et al. (1990) |
| 22 | Ternatins B1 | Flowers | Terahara et al. (1990) |
| 23 | Ternatins B2 | Flowers | Terahara et al. (1990), Terahara & Oda (1996) |
| 24 | Ternatins B3 | Flowers | Terahara & Oda (1996) |
| 25 | Ternatins B4 | Flowers | Terahara & Oda (1996) |
| 26 | Ternatins C1 | Flowers | Terahara (1998) |
| 27 | Ternatins C2 | Flowers | Terahara (1998) |
| 28 | Ternatins C3 | Flowers | Terahara (1998) |
| 29 | Ternatins C4 | Flowers | Terahara (1998) |
| 30 | Ternatins C5 | Flowers | Terahara (1998) |
| 31 | Ternatins D1 | Flowers | Terahara et al. (1990) |
| 32 | Ternatins D2 | Flowers | Terahara et al. (1990), Terahara & Oda (1996) |
| 33 | Ternatins D3 | Flowers | Terahara (1998) |
| 34 | PreternatinsA3 | Flowers | Terahara (1998) |
| 35 | PreternatinsC4 | Flowers | Terahara (1998) |
| 36 | Delphinidin 3-*O*-(2″-*O*-*α*-rhamnosyl-6″-*O*-malonyl)-*β*-glucoside | Flowers | Kazuma et al. (2003b) |
| 37 | Delphinidin 3-*O*-(6″-*O*-malonyl)-*β*-glucoside | Flowers | Kazuma et al. (2003b) |
| 38 | Delphinidin 3-neohesperidoside | Flowers | Kazuma et al. (2003b) |
| 39 | Delphinidin 3-*O*-*β*-glucoside | Flowers | Kazuma et al. (2003b) |

names and sources of the compounds and their specific structures are shown in Table 1, Figures 2, and 3.

## 4.2 Other Compounds

The other types of compounds in *C. ternatea* are mainly composed of lignans (**40**~**42**), triterpenoids (**43**, **44**), steroids (**45**, **46**), and organic acids (**47**~**65**), Banerjee & Chakravarti (1963, 1964) isolated two pentacyclic triterpenoids, taraxerol and taraxerone, from the roots of *C. ternatea*. Additionally, three novel lignan compounds, Clitorienolactones A-C, were isolated from the roots (Vasisht et al., 2016). Furthermore, Joshi et al. (1981) analyzed the seed oil and found

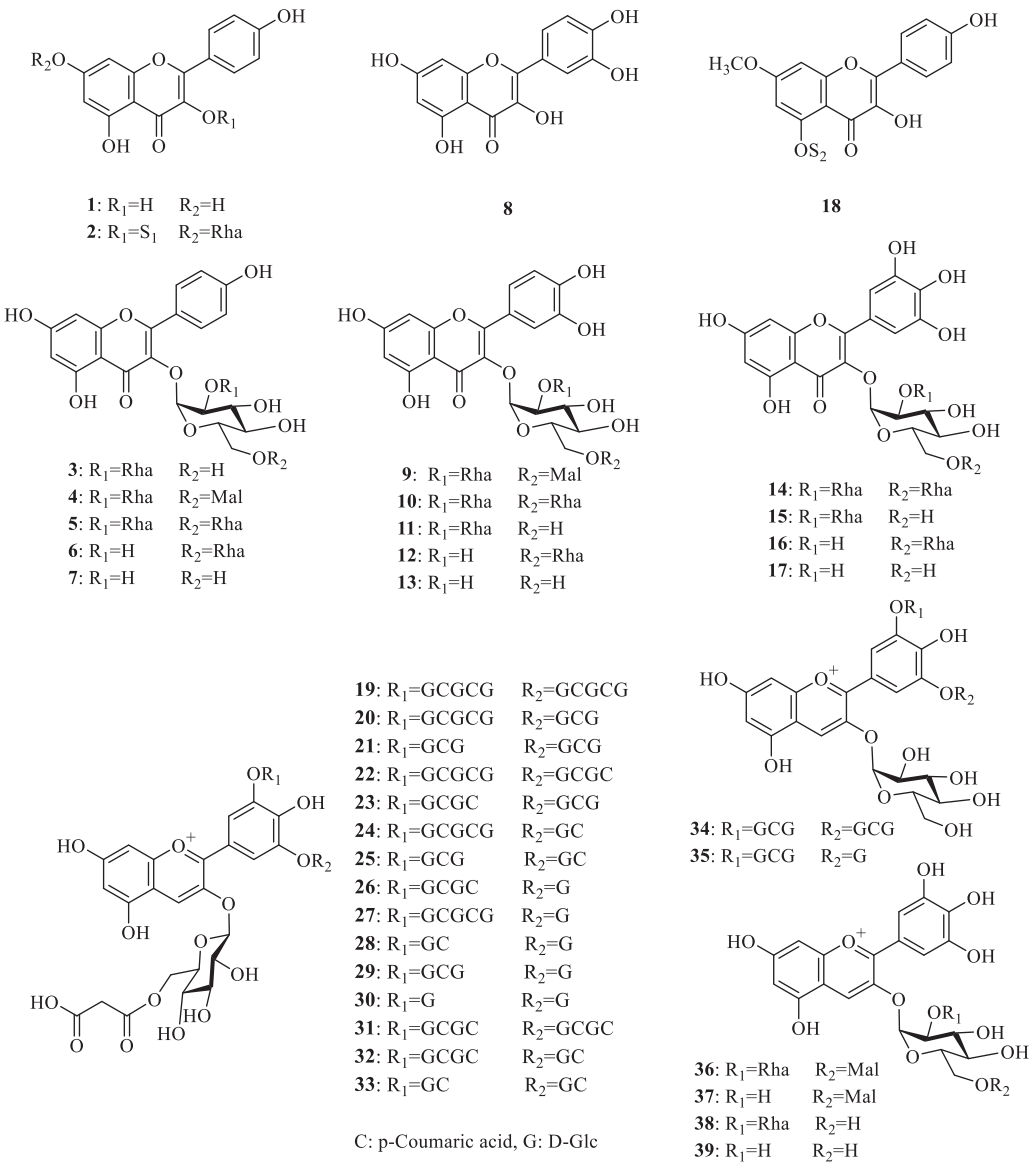


**Figure 2.** Chemical structures of the flavonoids in *C. ternatea*

its principal constituents to be fatty acids. Spandana et al. (2024) identified fourteen phenolic acid compounds in a 20% ethanol extract of the seed using UHPLC-ESI-MS/MS. These compounds and their structures are shown in Table 2 and Figure 4.

## 5 Pharmacological Activities

The extensive use of *C. ternatea* in traditional medicine has prompted researchers to dedicate themselves to elucidating the pharmacological activity of extracts from its various tissues (Figure 5). Numerous animal studies have demonstrated that these extracts possess multiple pharmacological effects, including antidiabetic, hypolipidemic, anti-cognitive decline, antibacterial, insecticidal, anti-inflammatory, analgesic, and antipyretic properties. The results of animal experiments and *in vitro* studies are summarized in Table 3.

### 5.1 Antidiabetic Activity

Common methods for evaluating hypoglycemic activity *in vitro* include α-glucosidase and α-amylase inhibition assays. Research indicates that the $IC_{50}$ values of the 80% ethanol extract of *C. ternatea* flower against α-glucosidase and α-amylase were 1.04 mg/mL and 1.70 mg/mL, respectively, whereas the $IC_{50}$ values of the reference drug acarbose were 2.76 mg/mL and 0.94 mg/mL, respectively (Li et al., 2022). Moreover, the water extract of *C. ternatea* flower also demonstrated effective inhibitory effects on both enzymes (Escher et al., 2020; Adisakwattana et al., 2012). Wu et al. (2024a) evaluated the hypoglycemic effects of *C. ternatea* flower using an *in vitro* bovine serum albumin (BSA) model, revealing a maximum inhibition rate of advanced glycation end products (AGEs) reaching 92.11%. These findings indicate that *C. ternatea* extract possesses significant hypoglycemic potential.


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**Table 2.** Other compounds from *C. ternatea*

| No. | Compounds | Parts | Ref. |
|---|---|---|---|
| 40 | Clitorienolactone A | Roots | Vasisht et al. (2016) |
| 41 | Clitorienolactone B | Roots | Vasisht et al. (2016) |
| 42 | Clitorienolactone C | Roots | Vasisht et al. (2016) |
| 43 | Taraxerol | Roots | Banerjee & Chakravarti (1963), Vasisht et al. (2016) |
| 44 | Taraxerone | Roots | Banerjee & Chakravarti (1964) |
| 45 | $\beta$-Sitosterol | Seeds, Leaves | Kulshrestha & Khare (1968) |
| 46 | γ-Sitosterol | Seeds, Leaves | Sinha (1960) |
| 47 | 2,4-dihydroxybenzoic acid | Seeds | Spandana et al. (2024) |
| 48 | Gallic acid | Seeds, Flowers | Spandana et al. (2024), Azima et al. (2017) |
| 49 | Gentisic acid | Seeds | Spandana et al. (2024) |
| 50 | *p*-hydroxybenzoic acid | Seeds | Spandana et al. (2024) |
| 51 | Protocatechuic acid | Seeds, Flowers | Spandana et al. (2024), Azima et al. (2017) |
| 52 | Salicylic acid | Seeds | Spandana et al. (2024) |
| 53 | Syringic acid | Seeds | Spandana et al. (2024) |
| 54 | Vanillic acid | Seeds | Spandana et al. (2024) |
| 55 | Caffeic acid | Seeds | Spandana et al. (2024) |
| 56 | Chlorogenic acid | Seeds, Flowers | Spandana et al. (2024), Azima et al. (2017) |
| 57 | Ferulic acid | Seeds | Spandana et al. (2024) |
| 58 | *o*-Coumaric acid | Seeds | Spandana et al. (2024) |
| 59 | *p*-Coumaric acid | Seeds | Spandana et al. (2024) |
| 60 | *trans*-cinnamic acid | Seeds | Spandana et al. (2024) |
| 61 | Palmitic acid | Seeds | Joshi et al. (1981) |
| 62 | Stearic acid | Seeds | Joshi et al (1981) |
| 63 | Oleic acid | Seeds | Joshi et al. (1981) |
| 64 | Linoleic acid | Seeds | Joshi et al. (1981) |
| 65 | Linolenic acid | Seeds | Joshi et al. (1981) |

Research has found that *C. ternatea* flowers can lower blood glucose levels in diabetic model rats, increase serum insulin levels, and exert therapeutic effects against diabetes through antioxidant, anti-inflammatory, and glucose metabolism-regulating mechanisms. In a rat model of diabetes complicated by dyslipidemia, the 70% ethanol extract of *C. ternatea* flower increased serum CAT and SOD levels while reducing MDA content, thereby alleviating oxidative stress. It also reduces levels of inflammatory mediators such as IL-6 and IL-18 in the pancreas and improves hepatic tissue lesions. Furthermore, it downregulates the expression of genes associated with glycogen synthesis and GSK-3$\beta$ (Widowati et al., 2023). Another study also indicates that *C. ternatea* flowers can inhibit the expression of inflammatory mediators IL-1$\beta$ and CRP while reducing the release of liver enzymes such as AST, ALT, LDH, and ACP to treat diabetes (Widowati et al., 2024). Daisy & Rajathi (2009) demonstrated that extracts from *C. ternatea* leaves and flowers, when administered to rats with diabetes induced by alloxan, exerted a hypoglycemic effect. This was achieved by reducing the activity of hyperglycemic enzymes such as glucose gluconolactonase while simultaneously enhancing the activity of hypoglycemic enzymes, including serum insulin (Daisy & Rajathi, 2009). Chusak et al. (2018) demonstrated through experiments that blood glucose and insulin levels in individuals remained suppressed for up to 30 minutes after consuming *C. ternatea* flower beverages. Furthermore, consumption of this beverage alone did not alter fasting blood glucose or insulin concentrations. Furthermore, extracts from different parts of the *C. ternatea* possess distinct biological activities. Compared to flower extracts, root and leaf extracts significantly ameliorate cognitive and behavioral impairments in diabetic rats (Rajashree et al., 2017; Talpate et al., 2014; 2013). In summary, *C. ternatea* holds significant potential in the treatment of diabetes.

### 5.2 Hypolipidemic Activity

Hyperlipidemia is one of the primary contributing factors to atherosclerosis and cardiovascular disease. *C. ternatea*, as a natural resource with multiple potential benefits, has demonstrated significant efficacy in lowering cholesterol, combating obesity, and regulating blood lipids. It has been reported that *C. ternatea* flower water extract inhibits early adipogenic differentiation in 3T3-L1 cells by suppressing the Akt1 and ERK1/2 signaling pathways, thereby downregulating the expression of PPARγ and C/EBP$\alpha$. This reduces the number of adipocytes and decreases lipid accumulation (Chayaratanasin et al., 2019). Moreover, *C. ternatea* flower water extract exerts a protective effect on mice rendered obese by a high-fat, high-fructose diet. It reduces plasma levels of leptin, free fatty acids, and low-density lipoprotein cholesterol, while demonstrating significant hypolipidemic

**Table 3.** Pharmacological activities of *C. ternatea*

| Pharmacological activities/Tissue | Extraction solvent/ Fraction | Types | Testing subjects | Doses/duration | Effects/mechanisms | Ref. |
|---|---|---|---|---|---|---|
| **Antidiabetic activity** | | | | | | |
| Leaves, Flowers | Water | *In vivo* | Alloxan-induced diabetes rat model | 400 mg/kg/d, i.g. for 84 days | Blood glucose, glycosylated hemoglobin, glucose-6-phosphatase ↓; serum insulin, glycogen, glucokinase ↑ | Daisy & Rajathi (2009) |
| Roots | Ethanol | *In vivo* | STZ-induced young diabetic rat model | 100 mg/kg/d, i.g. for 30 days | Blood glucose ↓ | Rajashree et al. (2017) |
| Leaves | Ethanol | *In vivo* | STZ-induced diabetic rat model | 200, 400 mg/kg/d, i.g. for 14 days | Acetylcholinesterase activity, TBARS, NO ↓; SOD, CAT, GSH ↑ | Talpate et al. (2014) |
| Leaves | Ethanol | *In vivo* | STZ-induced diabetic rat model | 200, 400 mg/kg/d, p.o. for 14 days | Fasting serum glucose, TBARS, total nitric oxide, ↓; SOD, CAT, GSH ↑ | Talpate et al. (2013) |
| Aerial parts | Ethanol | *In vivo* | STZ-induced diabetic rat model | 100, 200 mg/kg/d, p.o. for 21 days | Blood glucose, LPO, LDL, TG, total cholesterol ↓; body weight, SOD, CAT, GSH, HDL ↑ | Jain et al. (2003) |
| Flowers | Ethanol | *In vivo* | STZ-induced diabetic rat model | 100, 200 mg/kg/d, p.o. for 21 days | Mitigating cognitive deficits, enhancing synaptic density expression | Morampudi et al. (2024) |
| Flowers | 70% Ethanol | *In vivo* | HFD/NA/STZ induced diabetic rat model | 200, 400, 800 mg/kg/d, p.o. for 28 days | Blood glucose, MDA, IL-6, IL-18, GSK-3$\beta$ ↓; SOD, CAT ↑ | Widowati et al. (2023) |
| Flowers | 70% Ethanol | *In vivo* | HFD/NA/STZ induced diabetic rat model | 200, 400, 800 mg/kg/d, p.o. for 28 days | Blood glucose, MDA, LDH, ACP, serum bilirubin, ALT, AST, IL-1$\beta$, NOS, COX, PLA2 ↓; liver protein, SOD, CAT ↑ | Widowati et al. (2024) |
| Flowers | Ethanol | *In vivo* | HFD/NA/STZ induced diabetic rat model | 200, 400, 800 mg/kg | SMAD3, SMAD4, Glucagon, REG1A, REG1B ↓; body weight ↑ | Darsono et al. (2023) |
| Flowers | Water | *In vivo* | Alloxan-induced diabetic rat model | 300, 500 mg/kg/d, p.o. for 14 days | Blood glucose, SREBP-1, FAS ↓; GLUT4, PPARγ, GLUT2, SIRT1, Tfam ↑ | Sasmana et al. (2024) |
| Flowers | Ethanol | *In vitro* | BSA models | 0.01, 0.1, 1 g/mL | The inhibition rates were 92.11% at 1 g/mL, 56.99% at 0.1 g/mL, and 9.94% at 0.01 g/mL, respectively. | Wu et al. (2024a) |
| Flowers | 80% Ethanol | *In vitro* | $\alpha$-amylase, $\alpha$-glucosidases | 0.45~3.60 mg/mL | $IC_{50}$ = 1.70, 1.04 mg/mL | Li et al. (2022) |

**Table 3.** (Continued)

| Pharmacological activities/Tissue | Extraction solvent/ Fraction | Types | Testing subjects | Doses/duration | Effects/mechanisms | Ref. |
|---|---|---|---|---|---|---|
| Flowers | Water | *In vitro* | α-amylase, α-glucosidases | 1~20 mg/mL | The maximum inhibition rates were 38% and 20%. | Escher et al. (2020) |
| Flowers | Water | *In vitro* | α-amylase, α-glucosidases (maltase, sucrase) | 1~5 mg/mL | $IC_{50}$ = 4.05, 3.15, 4.41 mg/mL | Adisakwattana et al. (2012) |
| Flowers | Water | *In vitro* | α-amylase | 1~10 mg/mL | The maximum inhibition rates were 90%. | Hungerford et al. (2019) |
| **Hypolipidemic activity** | | | | | | |
| Flowers | 80% Ethanol | *In vitro* | Lipase | 0.075~0.60 mg/mL | $IC_{50}$ = 0.28 mg/mL | Li et al. (2022) |
| Flowers | Water | *In vitro* | 3T3-L1 Cells | 500, 750, 1000 μg/mL | Akt1, trriglyceride accumulation, PPARγ, C/EBPα ↓; lipolysis ↑ | Chayaratanasin et al. (2019) |
| Flowers | Water | *In vivo* | HFFD-induced mice model | 0.25%, 0.5%, 2%, p.o. for 16 weeks | Body weight, TC, FFA, LDL-C, TNF-α, IL-1β, IL-6, IFN-γ, MDA ↓; IL-4, IL-10, SOD, CAT, GSH, HDL-C, PPARγ, LXRα ↑ | Wang et al. (2022) |
| Seeds, Roots | 50% Ethanol | *In vivo* | Poloxamer 407-induced hyperlipidemia in rats; Diet-induced hyperlipidemia in rats | 500 mg/kg, p.o. | TC, TG, LDL-C, VLDL-C, MDA, NO, MPO, atherogenic index ↓; SOD, CAT, GSH, TAA, LAA ↑ | Solanki and Jain (2010) |
| Flowers | Water | *In vivo* | HFD-fed-induced obesity and dyslipidemia model | 250, 500, 750 mg/kg | TC, TG, LDL, VLDL, atherogenic index, cardiac risk factor ↓ | Sasmana et al. (2024) |
| **Anti-cognitive decline** | | | | | | |
| Roots | Water | *In vivo* | Wistar rats (7 and 60 days old) | 100 mg/kg, p.o. for 30 days | ACh ↑ | Rai et al. (2002) |
| Roots | Methanol | *In vivo* | Chronic cerebral hypoperfusion (CCH) rat model | 100, 200, 300 mg/kg, i.g. | Improve memory, rescue long-term potentiation | Damodaran et al. (2018) |
| Roots | Water | *In vivo* | Wistar rats (60 days old) | 50, 100 mg/kg/d, i.g. for 30 days | Increased dendritic intersections, branching points and dendritic processes arising | Rai et al. (2005) |
| Whole plant | Coarse plant powder | *In vivo* | Wistar rats (1, 12 and 18 months old) | 3 g/kg/d, i.g. for 60 days | Hippocampal CA3 cellularity ↑; autophagy ↓ | Raghu et al. (2017) |
| Roots, Flowers | 70% Methanol | *In vitro* | Acetylcholinesterase, Butyrylcholinesterase | 0~500 μg/mL | Flower, root and combination: AChE: $IC_{50}$ = 148.8 ± 0.14, 114.8 ± 0.21, 81.91 ± 0.19 μg/mL. BChE: $IC_{50}$ = 152.6 ± 0.01, 139.8 ± 0.11, 91.48 ± 0.23 μg/mL | Chowdhury et al. (2025) |

**Table 3.** (Continued)

| Pharmacological activities/Tissue | Extraction solvent/ Fraction | Types | Testing subjects | Doses/duration | Effects/mechanisms | Ref. |
|---|---|---|---|---|---|---|
| Roots, Flowers | 70% Methanol | *In vivo* | Scopolamine-induced Alzheimer mice model | 200, 400 mg/kg, p.o. | Enhancing memory; ACh, SOD, CAT, GSH ↑; AChE, BChE ↓ | Chowdhury et al. (2025) |
| Roots | Clitorienolactone A, B | *In vivo* | The rat model of CCH was induced using two-vessel occlusion surgery (2VO) | 10 mg/kg | Hippocampal long-term, synaptic plasticity, $Ca^{2+}$ ↑ | Ahad et al. (2024) |
| Roots | Methanol | *In vivo* | CCH rat model | 100, 200, 300 mg/kg, p.o. for 28 days | AChE, neuronal damage in the CA1 region ↓ | Damodaran et al. (2020) |
| Roots | Ethanol | *In vivo* | propionic acid-induced autistic rat model | 250, 500 mg/kg/d, p.o. for 28 days | TNF-*α*, IL-6, GFAP, CD68 ↓ | Jiji & Muralidharan (2022) |
| Roots | Ethanol | *In vivo* | Wistar rats | 300, 500 mg/kg/d, p.o. for 7 days | ACh activity ↑ | Taranalli & Cheeramkuzhy (2000) |
| Roots | Ethanol | *In vivo* | propionic acid-induced autistic rat model | 250, 500 mg/kg/d, p.o. for 28 days | TL, RL, 5-HT, Glutamic acid ↓ | Jiji & Muralidharan (2021) |
| **Antibacterial activity** | | | | | | |
| Flowers | *Clitoria ternatea* anthocyanin fraction | *In vitro* | *Escherichia coli* ATCC 25922 | 5, 10, 20 mg/mL | MIC = 10 mg/mL Phospholipid, glycerophospholipid, amino acid, and energy metabolism ↓ | Jeyaraj et al. (2023) |
| Flowers | *Clitoria ternatea* anthocyanin fraction | *In vitro* | *Streptococcus mutans*, *Actinomyces Viscosus*, *Aggregatibacter actinomycetemcomitans* | 0~15 mg/mL | MIC = 7.5, 7.5, 15 mg/mL Biofilm formation, EPS, acid production ↓ | Sathiaseelan et al. (2025) |
| Flowers | ethyl acetate | *In vitro* | *Coniochaeta hoffmannii* | 1000, 1500, 2000, 2500 μg/mL | MIC = 0.5 mg/mL, MFC = 1 mg/mL Biofilm formation ↓ | Yolin et al. (2024) |
| Flowers | ethanol | *In vitro* | *Staphylococcus aureus*, *E. coli* *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Enterococcus faecalis* | 25, 50, 100 μL | The largest zones of inhibition were observed against *S. aureus*. | Surya et al. (2024) |
| Flowers | *Clitoria ternatea* anthocyanin fraction | *In vitro* | *P. aeruginosa* | 0.313~5.0 mg/ml | biofilm inhibitory activity | Jeyaraj et al. (2022b) |
| Flowers | *Clitoria ternatea* anthocyanin fraction | *In vitro* | *Bacillus cereus, B. subtilis, E. coli*, | 0.16~40 mg/mL | MIC = 0.63, 0.63, 10 mg/mL | Jeyaraj et al. (2022a) |

**Table 3.** (Continued)

| Pharmacological activities/Tissue | Extraction solvent/ Fraction | Types | Testing subjects | Doses/duration | Effects/mechanisms | Ref. |
|---|---|---|---|---|---|---|
| Seeds | Ct protein | *In vitro* | *Candida albicans*, *C. glabrata*, *C. tropicalis*, *C. parapsilosis*, *Cryptococcus neoformans*, *C. laurentii*, *C. albidus* | 0.25~512 μg/mL | MIC = 16, >32, >32, 16, 8, 16, 8 μg/mL<br>MFC = 32, >32, >32, 32, 16, 32, 16 μg/mL | Ajesh and Sreejith (2014) |
| Seeds, Root | cT15~cT21 | *In vitro* | *E. coli*, *S. aureus* | 0.5~100 μM | cT15 and cT20 exhibit bactericidal activity against *E. coli*. | Nguyen et al. (2016) |
| Seeds | Cationic peptide | *In vitro* | *albicans*, *S. aureus*, *Aeromonas hydrophila*, *E. coli* | 1~128 μg/mL | MIC = 8, 16, 32, 32 μg/mL | Sreekala & Muraleedharan (2021) |
| Mature pods | Cyclotides M1 and M2 | *In vitro* | *B. subtilis*, *P. aeruginosa* | 50 mg/mL | Antibacterial efficacy against *B. subtilis* (inhibition diameters: 17.83~19.67 mm) and *P. aeruginosa* (inhibition diameters: 19.33~20.33 mm). | Tran et al. (2023) |
| **Insecticidal activity** | | | | | | |
| Seeds | Methanol | *In vitro* | *Anopheles stephensi*, *Aedes aegypti*, *Culex quinquefasciatus* | 1000 ppm | $LC_{50}$ = 65.2, 154.5, 54.4 ppm | Mathew et al. (2009) |
| Seeds | CteTAI | *In vitro* | *Spodoptera frugiperda* | 100, 200, 300 ppm | Relative growth rate decreased by 44%. Relative consumption rate decreased by 40%. Percentage efficiency of conversion of ingested food decreased by 29%. Percentage feeding deterrence index is 45% | Dongare et al. (2025) |
| Seeds | Finotin | *In vitro* | *Zabrotes subfasciatus*, *Acanthoscelides obtectus* | 0~5% w/w | $LC_{50}$ = 1.21%; $LC_{95}$ = 2.88%; At a concentration of 5%, *Z. subfasciatus* exhibited 100% mortality.<br>$LC_{50}$ = 0.36%; $LC_{95}$ = 0.77%; At a concentration of 1%, *A. obtectus* exhibited 100% mortality. | Kelemu et al. (2004) |
| **Anti-inflammatory, analgesic and antipyretic activity** | | | | | | |
| Leaves<br>Roots | Methanol | *In vivo* | Sprague-Dawley male rats | 100, 200, 400 mg/kg, p.o. | Paw licking time ↓; pain latency ↑ | Kamilla et al. (2014) |
| Roots | Methanol | *In vivo* | Wistar rats and Swiss mice | 200, 400 mg/kg, p.o. | Inhibit edema and inflammation; reduce body temperature; reduce the number of writhings. | Devi et al. (2003) |
| Roots | Methanol | *In vivo* | Albino rats | 200, 300, 400 mg/kg, p.o. | Lower the body temperature of rats with fever | Devi et al. (2004) |

**Table 3.** (Continued)

| Pharmacological activities/Tissue | Extraction solvent/ Fraction | Types | Testing subjects | Doses/duration | Effects/mechanisms | Ref. |
|---|---|---|---|---|---|---|
| Roots | Ethanol | *In vivo* | Carrageenan-induced paw edema model, Histamine-induced paw edema model, CFA-induced arthritis model | 200, 400 mg/kg | At doses of 200 mg/kg and 400 mg/kg, the maximum inhibition rates of edema were 89.13% and 81.39%, respectively. PGs, ROS, MDA ↓; SOD, CAT, GSH ↑ | Swathi et al. (2021) |
| Flowers | 80% Methanol | *In vivo* | Carrageenan-induced paw edema model in male Swiss albino mice Acid-induced writhing in male Swiss albino mice | 200, 400 mg/kg | The doses of 200 and 400 mg/kg, respectively, inhibited carrageenan-induced foot swelling by 65.28% and 81.89%, and reduced acetic acid-induced twisting by 75.6% and 76.78%. | Ahmed et al. (2024) |
| **Anti-tussive and anti-asthmatic activity** | | | | | | |
| Flowers | Ethanol | *In vitro* | Goat tracheal chain and isolated guinea pig ileum | 10 mg/mL | Inhibits contraction of the trachea and ileum. | Singh et al. (2018) |
| Flowers | Ethanol | *In vivo* | Guinea pigs exposed to histamine aerosol, OVA-sensitized mice | 100, 200, 400 mg/kg, p.o. | Total leukocytes, neutrophiles, eosinophiles, macrophages, lymphocytes, IL-1$\beta$, IL-6, IgG1 ↓ | Singh et al. (2018) |
| Roots | 95% Ethanol | *In vivo* | Clonidine-induced catalepsy in mice, | 100, 125, 150 mg/kg, i.p. | Inhibit clonidine-induced catalepsy | Taur & Patil (2011a) |
| Roots | 95% Ethanol | *In vivo* | Milk-induced leucocytosis and eosinophilia in mice, Passive cutaneous anaphylaxis in rats, Egg albumin-induced mast cell degranulation in mice | 100, 125, 150 mg/kg, i.p. | Leukocytes, eosinophiles, dye extravasation ↓ Stabilization of mast cells | Taur & Patil (2011b) |
| **Anticancer activity** | | | | | | |
| Flowers | 45% Ethanol | *In vitro* | T24, UM-UC-3, and J82 cells | 0.5~2.5 μg/mL | $IC_{50}$ = 34.40, 41.44, 52.72 μg/mL | Liu et al. (2025) |
| Flowers | 45% Ethanol | *In vivo* | Zebrafish xenograft model; bladder cancer xenograft nude mouse model | 15/60 μg/mL 200 mg/kg | SREBP1, FASN, ACC, SCD1, fatty acid levels ↓ | Liu et al. (2025) |
| Flowers | Methanol | *In vitro* | MDA-MB-231 cells, MCF-7 cells | 0~2.5 mg/mL | MDA-MB-231 cells: $IC_{50}$ = 0.11 mg/mL MCF-7 cells: $IC_{50}$ = 1.14 mg/mL | Akter et al. (2013) |
| Leaves | Methanol | *In vitro* | MDA-MB-231 cells, MCF-7 cells | 0~2.5 mg/mL | MDA-MB-231 cells: $IC_{50}$ = 0.49 mg/mL MCF-7 cells: $IC_{50}$ = 1.70 mg/mL | Akter et al. (2013) |
| Leaves | Ethanol | *In vitro* | HCT116, MCF-7, TT cells | 0.4~100 μg/mL | $IC_{50}$ = 29.2, 55.7, 61.6 μg/mL GAX, DIABLO ↑; NAIP1 ↓ | Alshamrani et al. (2022) |

**Table 3.** (Continued)

| Pharmacological activities/Tissue | Extraction solvent/ Fraction | Types | Testing subjects | Doses/duration | Effects/mechanisms | Ref. |
|---|---|---|---|---|---|---|
| Whole plant | Chloroform | *In vitro* | HepG2, HeLa cells | 62.5, 125, 250, 500, 1000 μg/mL | $IC_{50}$ = 110.0, 104.5 μg/mL | Kanthal et al. (2016) |
| **Antioxidant activity** | | | | | | |
| Leaves | Methanol | *In vitro* | DPPH• | 1 mg/mL | Scavenging DPPH•; $IC_{50}$ = 420.00 μg/mL | Nithianantham et al. (2011) |
| Flowers | Water | *In vitro* | DPPH•, AAPH-induced erythrocyte hemolysis model | 50, 100, 200, 400 μg/mL | Scavenging DPPH•; $IC_{50}$ = 0.47 mg/mL; membrane lipid peroxidation, protein carbonyl group formation, MDA ↓; GSH ↑ | Phrueksanan et al. (2014) |
| Flowers | Water | *In vitro* | DPPH•, $O_2^-$• | 0.25, 0.50, 1.00 mg/mL | Scavenging DPPH•, $O_2^-$•; $IC_{50}$ = 0.47, 0.58 mg/mL | Chayaratanasin et al. (2015) |
| Flowers | Water | *In vitro* | DPPH•, $ABTS^+$•, HaCaT cell line | 0, 50, 100, 250, 500 μg/mL | Scavenging DPPH•, $ABTS^+$•; $IC_{50}$ = 195.5, 42.9 μg/mL; against $H_2O_2$-induced cell death | Zakaria et al. (2018) |
| Flowers | Water | *In vitro* | DPPH•, $Fe^{3+}$ | 1, 3, 5, 8, 14 μg/mL 5.76, 9.60, 17.28, 24.00, 32.00, 48.00 μg/mL | Scavenging DPPH•; $IC_{50}$ = 5.34 μg/mL FRAP: 0.33 mmol AAeq/mg | Iamsaard et al. (2014) |
| Flowers | Water | *In vitro* | $O_2^-$•, •OH | 0.125~1 mg/mL | Scavenging $O_2^-$•, •OH | Chayaratanasin et al. (2021) |
| Stem | Acetone, methanol | *In vitro* | DPPH•, $O_2^-$•, •OH, β-Carotene Linoleate Model | 200, 400, 600, 800, 1000 μg/mL | Scavenging DPPH•, $O_2^-$•, •OH; Acetone: $IC_{50}$ = 758.58, 451.85, 141.25 μg/mL Methanol: $IC_{50}$ = 933.25, 288.40, 52.48, 841.39 μg/mL | Jain et al. (2010) |
| **Others** | | | | | | |
| Flowers | Water | *In vivo* | L-NAME-induced hypertension rats | 300 mg/kg/day, p.o. for 5 weeks | SBP, DBP, serum creatinine, ECM, Ang II, Nox4, MDA ↓ | Saengnak et al. (2021) |
| Flowers | Water | *In vivo* | L-NAME-induced hypertension rats | 300 mg/kg/day, p.o. for 5 weeks | Blood pressure, $O_2^-$•, MDA, ACE, Ang II, $AT_1R$, NOX2, p-NF-κB, TNF-α ↓ CAT, Nox, eNOS↑ | Maneesai et al. (2021) |
| Leaves | Water | *In vivo* | Cisplatin-induced acute kidney injury in rats | 400 mg/kg/day, p.o. for 21 days | Serum creatinine, urea, uric acid, MDA, IL-6, IL-1β, caspase-3 ↓; SOD, GSH ↑ | Safhi et al. (2022) |
| Leaves | Methanol | *In vivo* | Paracetamol-induced hepatotoxicity model in mice | 200 mg/kg, p.o. for 7 days | ALT, AST, bilirubin levels ↓ | Nithianantham et al. (2011) |

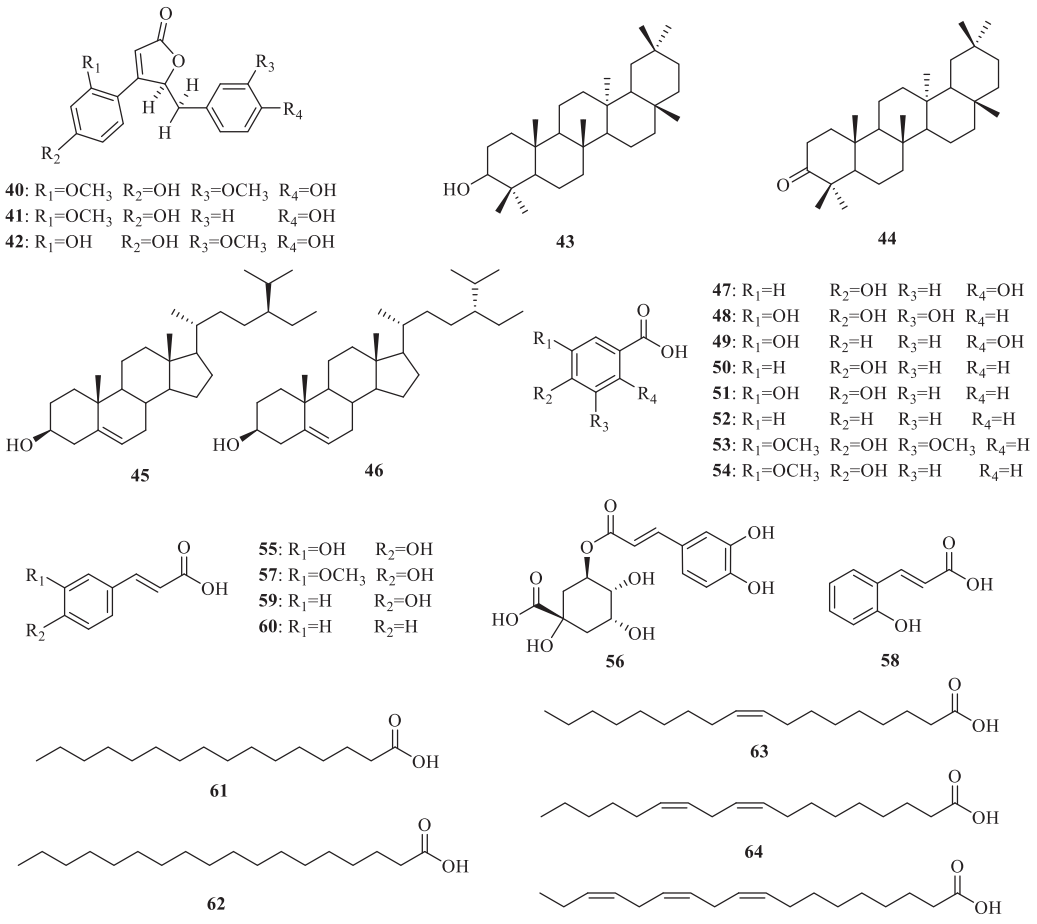


**Figure 3.** Chemical structures of other compounds in *C. ternatea*

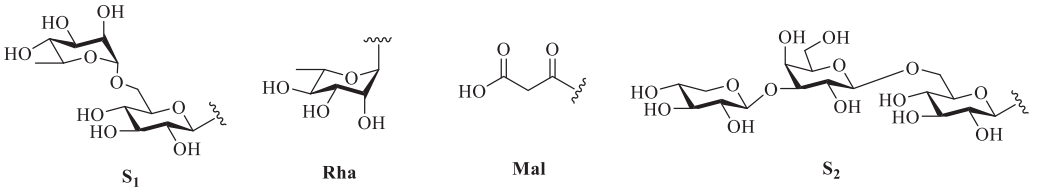


**Figure 4.** The structures of substituents appear in the paper

effects by promoting cholesterol reverse transport (Adisakwattana et al., 2012). Yogendrasinh et al. investigated the hypolipidemic effects of *C. ternatea* extract in rats with acute hyperlipidemia induced by porlosam 407 and in rats with diet-induced hyperlipidemia. Results indicate that both water-ethanol extracts of *C. ternatea* roots and seeds significantly reduce serum TC and TG levels while improving the ratio of HDL to LDL. In a diet-induced hyperlipidemia model, both the atherosclerosis index and the HDL/LDL ratio returned to normal levels following treatment. Its cholesterol-lowering mechanism may be related to promoting bile excretion, reducing dietary cholesterol absorption, and enhancing the body's antioxidant capacity (Solanki & Jain, 2010). A study indicates that for overweight and obese individuals, ingesting *C. ternatea* flower extract can effectively reduce serum TG and FFA levels following a high-fat meal, whilst simultaneously improving plasma antioxidant status and GSH-Px activity. Results indicate that for overweight and obese individuals who frequently consume high-fat diets, *C. ternatea* flower extract may function as a functional ingredient, suppressing postprandial lipid elevation and enhancing antioxidant capacity (Thilavech et al., 2021).

### 5.3 Anti-cognitive Decline

*C. ternatea* is an herb used in folk medicine as a memory enhancer. In India, its roots are frequently employed in the treatment of mental disorders and a variety of other ailments. Rai et al. (2002) found that following 30 days of treatment with *C. ternatea* root water extract in newborn and young adult rats. The experimental group exhibited significantly higher ACh levels in the hippocampus compared to


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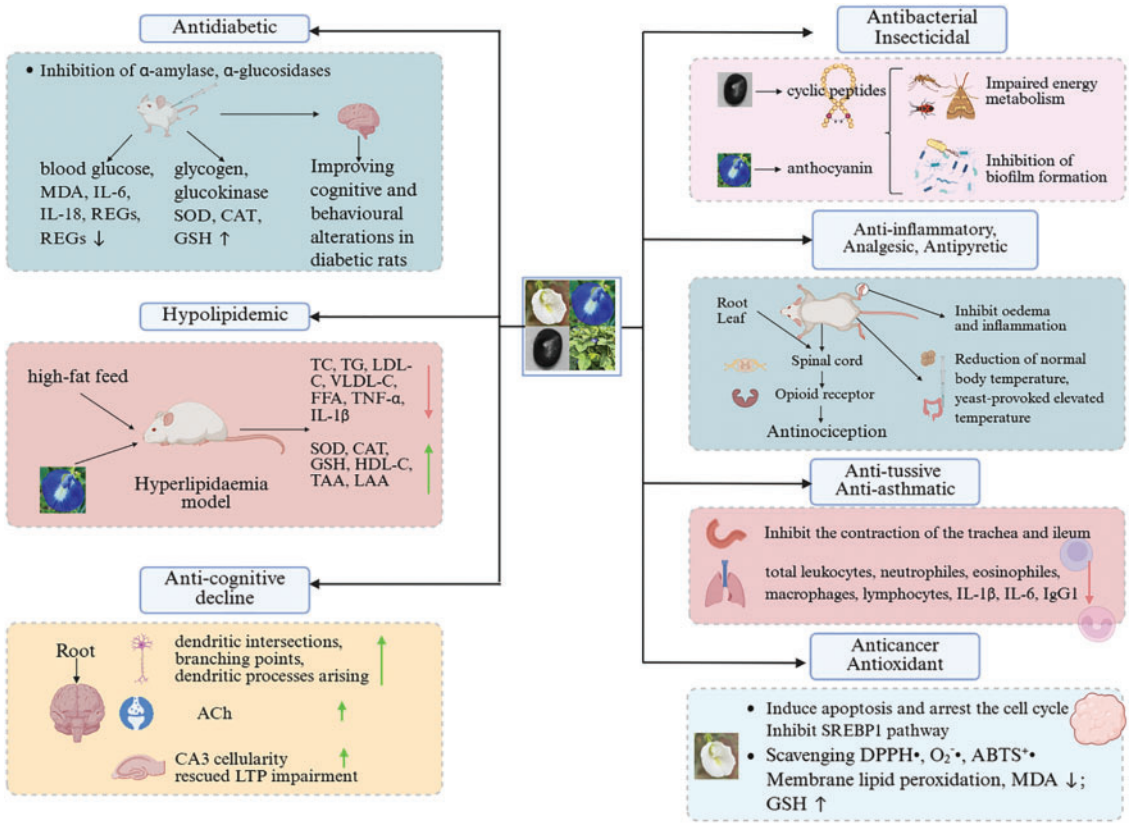


**Figure 5.** Main pharmacological activities of *C. ternatea* and their corresponding mechanisms of action

the age-matched control group and demonstrated improved learning and memory capabilities in rats. Damodaran et al. (2018) performed permanent bilateral occlusion of common carotid arteries in male rats. For 28 consecutive days post-surgery, methanol extracts of *C. ternatea* root were administered via gastric lavage. The effects on memory function in rats with chronic cerebral hypoperfusion were assessed through behavioral testing and electrophysiological recordings. Results indicate that extracts at 200 and 300 mg/kg significantly improved memory function in rats, with the mechanism potentially involving the restoration of damaged long-term depression in the hippocampus (Damodaran et al., 2018). Additionally, a 100 mg/kg root water extract increased synapses, branching points, and dendritic spines in rat amygdala neurons. This indicates that *C. ternatea* root water extract promotes dendritic arborization in amygdala neurons, thereby enhancing learning and memory capacity (Rai et al., 2005). Another study found that long-term administration of *C. ternatea* whole-plant extract significantly reduced autophagy levels in rats. It also increased cell numbers in the hippocampal CA3 region and inhibited neuronal apoptosis by selectively repairing DNA pathways and scavenging reactive oxygen species. This alleviated memory decline caused by aging and enhanced autophagy (Raghu et al., 2017). In summary, *C. ternatea* root holds potential application value in preventing vascular dementia and Alzheimer's disease, as well as enhancing memory function.

### 5.4 Antibacterial and Insecticidal Activity

*C. ternatea* possesses excellent antibacterial properties, with its primary active constituents being anthocyanins and polypeptide compounds. Ajesh & Sreejith (2014) isolated and purified an antifungal protein, Ct protein, from *C. ternatea* seeds. This protein exhibits inhibitory effects against *Micrococcus luteus* and demonstrates broad-spectrum fungicidal activity. Moreover, this protein inhibits the mycelial growth of various molds, including *Curvularia* sp., *Alternaria* sp., and *Cladosporium* sp., while exhibiting no hemolytic activity (Ajesh & Sreejith, 2014). Nguyen et al. (2016) isolated nine novel cyclic peptides, cliotides 15~21, from *C. ternatea*. These compounds exhibit potent antibacterial activity against Gram-negative bacteria, significantly inhibiting bacterial growth even at extremely low concentrations. And cT15 and cT20 exhibit rapid bactericidal activity against *Escherichia coli* (Nguyen et al., 2016). Moreover, the anthocyanin components in *C. ternatea* flowers exhibit significant antibacterial activity. Research indicates that the minimum inhibitory concentration (MIC) against *E. coli* ATCC 25922 is 10 mg/mL. At this concentration and at 20 mg/mL, exposure for four hours resulted in inhibition rates of 95.8% and 99.9%, respectively, against the growth of *E. coli*. Further mechanistic studies indicate that anthocyanin components significantly inhibit glycerophospholipid metabolism, amino acid metabolism, and energy metabolism. These pathways represent the key mechanisms through which *C. ternatea* anthocyanins exert their antibacterial effects (Jeyaraj et al.,

2023). Jeyaraj et al. (2022b) discovered that anthocyanin components exhibit significant biofilm-inhibiting activity against *Pseudomonas aeruginosa* and effectively reduce its adhesion to polystyrene surfaces. This indicates that the component holds promise for development as an anti-biofilm agent for treating infections caused by *Pseudomonas aeruginosa* (Jeyaraj et al., 2022b).

Mathew et al. (2009) compared the larvicidal activity of *Saraca indica*/*asoca*, *Nyctanthes arbortristis*, and *C. ternatea* against *Aedes aegypti*, *Culex quinquefasciatus*, and *Anopheles stephensi*. Results indicate that *C. ternatea* exhibited the most potent insecticidal activity, with its seed extract displaying median lethal concentrations ($LC_{50}$) of 65.2 ppm, 154.5 ppm, and 54.4 ppm against the three mosquito larvae species, respectively (Mathew et al., 2009). CteTAI, a novel protein derived from *C. ternatea* seeds, significantly inhibits the growth and development of *Spodoptera frugiperda*, causing nutritional metabolic disorders and morphological deformities (Dongare et al., 2025). It demonstrates potential as a biopesticide for use in green agricultural pest control.

### 5.5 Anti-inflammatory, Analgesic and Antipyretic Activity

In rat models of paw oedema induced by carrageenan and vascular permeability induced by acetic acid, the methanol extract of *C. ternatea* root demonstrated significant anti-inflammatory activity. Furthermore, its analgesic activity was evaluated via the acetic acid-induced mouse writhing test, with results indicating that the extract significantly reduced writhing episodes (Devi et al., 2003). The same study also found that at a dose of 400 mg/kg, the extract significantly reduced body temperature in yeast-induced febrile rats, with an effect comparable to that of paracetamol (Devi et al., 2003, 2004). Nair et al. (2015) found that flavonoids from *C. ternatea* flowers exhibit anti-inflammatory effects in a LPS-induced macrophage inflammation model. *C. ternatea* flowers primarily contain anthocyanins and quercetin glycosides, which exert anti-inflammatory effects synergistically through distinct mechanisms. Quercetin glycosides inhibit COX-2 enzyme activity, while anthocyanins exert their effects by suppressing the NF-$\kappa$B pathway and iNOS expression (Nair et al., 2015). Kamilla et al. (2014) conducted an in-depth study on the analgesic effects of *C. ternatea*, discovering that both its leaf and root extracts demonstrated significant analgesic effects in experimental animals, though their mechanisms of action differed. The analgesic effects of root extracts primarily occur at the vertebral body and spinal cord levels, whilst leaf extracts mainly exert their action through vertebral body sensitivity, potentially involving opioid receptor participation (Kamilla et al., 2014).

### 5.6 Anti-Tussive and Anti-Asthmatic Activity

*C. ternatea* is regarded as a promising herbal remedy for respiratory ailments, exhibiting properties such as anti-tussive, anti-asthmatic, and anti-allergic effects. Singh et al. (2018) investigated the effects of *C. ternatea* flower ethanol extract on mouse tracheal strips and guinea pig isolated ileum. They found that the extract significantly inhibited histamine-induced contractions in goat trachea and guinea pig ileum. It also prolonged the latency period of respiratory distress in guinea pigs following exposure to histamine aerosol. This indicates antihistamine activity both *in vivo* and *in vitro*. At a high dose of 400 mg/kg, the extract alleviated OVA-induced respiratory distress in mice, reducing the total number of inflammatory cells (particularly eosinophils and neutrophils), IL-1$\beta$, IL-6, and IgG1 antibody levels (Singh et al., 2018). Moreover, this extract effectively counteracts coughing induced by sulphur dioxide and citric acid, as evidenced by a reduction in cough frequency and an extension of the latency period. This research provides scientific evidence for the traditional use of *C. ternatea* flowers in treating respiratory diseases such as bronchitis and asthma. *C. ternatea* root ethanol extract exhibits antihistaminic effects by antagonizing histamine $H_1$ receptors, significantly inhibiting clonidine-induced tonic syncope (Taur & Patil, 2011a). Concurrently, it demonstrates pronounced anti-asthmatic and anti-allergic activity by stabilizing mast cells, suppressing inflammatory cell infiltration, and inhibiting mediator release (Taur & Patil, 2011b). The aforementioned research provides scientific evidence for the traditional use of *C. ternatea* flowers in treating respiratory diseases such as bronchitis and asthma.

### 5.7 Anticancer Activity

Liu et al. (2025) found that *C. ternatea* flower extract significantly inhibited the proliferation of bladder cancer cell lines T24, UM-UC-3, and J82 in a dose-dependent manner, with $IC_{50}$ values of 34.40, 41.44, and 52.72 μg/mL, respectively. Further *in vivo* studies confirmed that the extract significantly inhibits fatty acid synthesis by suppressing the SREBP1 pathway and its downstream key enzymes involved in lipid synthesis, thereby inhibiting tumor growth. Furthermore, it enhances the efficacy of cisplatin and exhibits synergistic effects when used in combination with gallic acid (Liu et al., 2025). Akter et al. (2013) compared the cytotoxic activity of various medicinal plants and found that *C. ternatea* exhibited significant cytotoxicity, particularly demonstrating potent inhibitory effects against breast and gastric cancer cell lines. The $IC_{50}$ values for the flower and leaf extracts against MDA-MB-231 cells were 0.11 and 0.49 mg/mL, respectively, while those against MCF-7 cells were 1.14 and 1.70 mg/mL, respectively (Akter et al., 2013).

### 5.8 Antioxidant Activity

Literature records indicate that *C. ternatea* possesses potent antioxidant activity, effectively scavenging multiple free radicals. Research by Chayaratanasin et al. (2015) revealed that its aqueous flower extract exhibited $IC_{50}$ values of 0.47 and 0.58 mg/mL against DPPH• and $O_2^-$•, respectively. Another study reported its $IC_{50}$ values against DPPH• and $ABTS^+$• as 195.5 and 42.9 μg/mL, respectively (Chayaratanasin et al., 2015). At the cellular level, this extract significantly inhibited $H_2O_2$-induced cell death within a concentration range of 100~500 μg/mL, while pretreatment at 250 μg/mL markedly


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mitigated UV-induced mitochondrial DNA damage. Furthermore, the extract demonstrated potent UV absorption capacity in both the UVC and UVB spectral bands (Zakaria et al., 2018). The anthocyanins and flavonoids in *C. ternatea* flowers constitute the primary components responsible for their antioxidant activity. Research indicates that this extract effectively protects canine red blood cells from AAPH-induced oxidative damage, including inhibiting hemolysis, lipid peroxidation, protein oxidation, and GSH depletion, while also aiding in the maintenance of normal red blood cell morphology (Phrueksanan et al., 2014). Moreover, the leaves and stems of *C. ternatea* also exhibit certain antioxidant activity.

### 5.9 Others

In addition to the aforementioned properties (Figure 6), *C. ternatea* also possesses the ability to lower blood pressure and protect against liver and kidney damage. Saengnak et al. (2021) discovered that *C. ternatea* flower extract protects against renal injury in L-NAME-induced hypertensive rats. Its mechanism involves inhibiting ACE activity, thereby reducing angiotensin II levels, which in turn suppresses NADPH oxidase 4 expression and diminishes reactive oxygen species (ROS) production. Concurrently, its antioxidant constituents directly scavenge ROS, lowering lipid peroxidation levels (Saengnak et al., 2021). *C. ternatea* flower water extract effectively prevents cardiovascular dysfunction in L-NAME-induced hypertensive rats. Its mechanism of action involves inhibiting renin-angiotensin system activation and mitigating oxidative stress and inflammatory responses, with efficacy comparable to the ACE inhibitor ramipril (Maneesai et al., 2021). A study has found that combined treatment with *C. ternatea* leaf extract and mesenchymal stem cells significantly improves cisplatin-induced acute kidney injury. It exerts a protective effect on renal tissue by reducing MDA levels, enhancing SOD and GSH activity, downregulating pro-inflammatory factor expression, and concurrently diminishing tubular cell apoptosis through inhibition of caspase-3 expression (Safhi et al., 2022). Additionally, *C. ternatea* leaf extract effectively mitigates paracetamol-induced liver damage in mice, with its mechanism of action primarily attributed to its rich polyphenolic and flavonoid constituents (Nithianantham et al., 2011).

## 6 Application

### 6.1 Cash Crop

*C. ternatea* possesses nitrogen-fixing properties. It can maintain soil fertility and enhance crop yields. This ability relies upon rhizobia that form a symbiotic relationship with the roots of *C. ternatea* plants. Roy & Basu (1992) investigated the conditions for the production of the plant growth hormone indole-3-acetic acid (IAA) in *C. ternatea* nodules. It was discovered that the majority of IAA within the nodules is produced by the symbiotic bacteria. This indicates that rhizobia not only possess nitrogen-fixing capabilities but also promote the growth of *C. ternatea* (Roy & Basu, 1992). Furthermore, based on the ability of *C. ternatea* to maintain soil fertility, Njunic et al. (2004) investigated the yields of cassava and maize under both monoculture and intercropping conditions. It has been demonstrated that intercropping *C. ternatea* with cereal crops can increase grain yields (Njunic et al., 2004). Clem & Hall (1994) investigated the persistence and productivity of *C. ternatea* as forage on clay pastures in Australia. Research indicates that *C. ternatea* demonstrates excellent performance in terms of survival rate, persistence, growth rate, and nitrogen-fixing capacity when used as forage. This has facilitated beef cattle grazing and cereal crop rotation in Australia (Clem & Hall, 1994). Concurrently, *C. ternatea* serves as an excellent forage crop, aiding the growth of companion pastures and rotational crops, enhancing soil fertility, improving soil structure, controlling weed populations, and preventing pests and diseases (Nichols et al., 2007). Grindley et al. (1954) found that *C. ternatea* seeds contained up to 41.19% protein and 11.76% oil, whereas *Entada phaseoloides* seeds contained 19.54% protein and 7.00% oil. This indicates that *C. ternatea* seeds may serve as a high-quality source of animal feed (Grindley et al., 1954). The above examples all demonstrate that *C. ternatea* could be a highly promising tropical cash crop, requiring further development and utilization.

### 6.2 Cigarette Additives

*C. ternatea* flowers may serve as a novel natural flavoring for tobacco products. Research has found that *C. ternatea* flower essential oil can be used to flavor cigarettes. It enhances the quality and aroma of tobacco, reduces harshness, and improves the aftertaste. This elevates the overall smoking experience (Xu et al., 2019). Han et al. (2019) compared the effects of ultrasonic extraction, supercritical $CO_2$ extraction, and molecular distillation on enhancing the quality of tobacco shreds when extracting volatile oils from *C. ternatea* flowers. The net oil obtained via supercritical $CO_2$ extraction yielded the highest number of identified volatile constituents, the greatest relative content, and the most favorable overall results. This method not only reduces the irritation, pungency, and astringency of the tobacco but also enhances its aroma and sweetness (Han et al., 2019). It has been demonstrated that *C. ternatea* flower essential oil constitutes an ideal additive for tobacco shreds.

### 6.3 Skin Protection Products

Skin aging is largely attributable to oxidative damage caused by reactive oxygen species. This damage may stem from multiple factors, including lifestyle choices, nutrition, and ischemia. Concurrently, excessive exposure to UV radiation can exacerbate surface deterioration, leading to wrinkles, hyperpigmentation, and skin laxity. In Thailand and other Southeast Asian countries, *C. ternatea* flower extract is widely used in cosmetics. Zakaria et al. (2018) demonstrated that *C. ternatea* flower water extracts exhibit antioxidant activity, with their primary active constituents being flavanol and anthocyanin compounds. Anthocyanins possess skin-protective and anti-aging properties, but owing to their water-soluble nature, they are prone to degradation in aqueous environments, resulting in diminished activity.

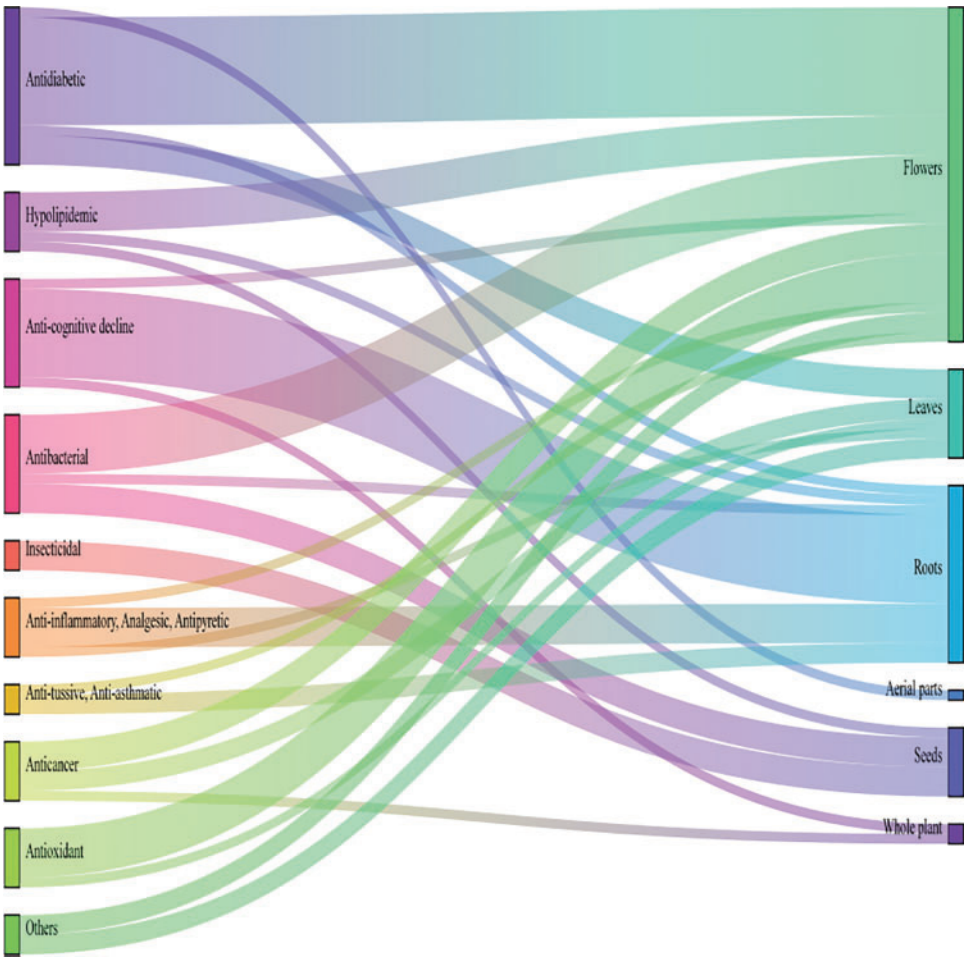


**Figure 6.** Relationship between the pharmacological activities and plant parts of *C. ternatea*. (https://www.chiplot.online/)

To enhance the stability of anthocyanins in *C. ternatea* flower extract (Zakaria et al., 2018), Aroonsri et al. developed an anthocyanin complex and tested its potential as a sunscreen. It was found to be non-cytotoxic to skin cells, enhancing the stability of total anthocyanins and enabling them to adhere effectively to the skin surface to exert a protective effect. The results confirmed that, following further development, this anthocyanin complex demonstrated potential for use as a topical sunscreen (Priprem et al., 2017). Kamkaen & Wilkinson (2009) evaluated the activity of *C. ternatea* flower water extracts and ethanol extracts in an eye gel. The water extract demonstrated significantly stronger DPPH• scavenging activity ($IC_{50}$ = 1 mg/mL) than the ethanol extract ($IC_{50}$ = 4 mg/mL). This indicates that the water extraction method is more suitable for isolating active components from *C. ternatea* flowers for cosmetic applications (Kamkaen & Wilkinson, 2009). Moreover, Mukherjee et al. evaluated the wound-healing potential of *C. ternatea* leaf extract through multiple skin wound-related enzyme models. Results revealed that the methanol extract inhibited hyaluronidase ($IC_{50}$ = 18.08 μg/ml) and elastase ($IC_{50}$ = 42.68 μg/ml). Furthermore, its inhibitory effect on matrix metalloproteinase-1 even surpassed that of the standard compound oleanolic acid. This indicates that the extract is suitable for use as a wound healing agent in the treatment of skin injuries (Maity et al., 2012).

### 6.4 Insecticide

It has been reported that proteins and peptides isolated from the *C. ternatea* exhibit significant insecticidal activity, demonstrating potential for development as insecticides (Oguis et al., 2019). Research by Mensah et al. (2015) indicates that applying a 1–2% oil-based *C. ternatea* mixture to cotton crops can disrupt the egg-laying and larval feeding of cotton bollworms, resulting in larval mortality. Moreover, it has no adverse effects on beneficial insects, further demonstrating its potential as an environmentally friendly insecticide (Mensah et al., 2015). Currently, the first insecticide based on *C. ternatea* extract, Sero-X®, has been registered for use in controlling pests on cotton and macadamia trees.

## 7 Conclusion and Perspectives

Approximately 65 chemical constituents, primarily flavonoids, have been isolated from *C. ternatea*. In recent years, no new chemical constituents have been reported from *C. ternatea*. Subsequent research may involve the systematic isolation of different parts of the *C. ternatea* plant


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to identify novel chemical constituents present therein. The chemical composition varies significantly across different parts of the *C. ternatea* plant. For instance, the flowers and leaves primarily contain flavonoid compounds. The roots predominantly contain lignin and triterpenoid compounds. And the seeds are rich in fatty acids and amino acid compounds. This compositional variation may be closely associated with biosynthetic pathways. Future research may employ metabolomics and transcriptomics to elucidate its synthesis mechanisms and determine the distribution of chemical constituents across different plant parts. This will enable the comprehensive development and utilization of the *C. ternatea*.

Like other traditional Chinese medicines possessed anti-tumor (Ding et al., 2020; Zhu et al., 2020, 2018), anti-inflammatory (Pu et al., 2019), antiviral (Zhang et al., 2022), immunosuppressive (Xu et al., 2023), anti pulmonary fibrosis (Shen et al., 2022; Liao et al., 2021), anti-diabetic (Wu et al., 2024b; Olatunji et al., 2023), anti myocardial injury (Chen et al., 2016), anti liver injury (Chen et al., 2019), anti renal injury (Zhang et al., 2019; Liao et al., 2019), and effects on bone metabolism activities (Tao et al., 2022; Yao et al., 2020; Xiao et al., 2020). *C. ternatea* possesses multiple pharmacological effects, including antidiabetic, hypolipidemic, anti-cognitive decline, antibacterial, insecticidal, anti-inflammatory, analgesic, antipyretic, and anti-cancer effects, and antioxidant activity. However, current research in this area remains largely confined to simple animal models. Modern pharmacological research into the identification of active ingredients, their mechanisms of action, pathways, and targets remains inadequate. In the future, systematic prediction and research into the active constituents of *C. ternatea* and their mechanisms of action may be conducted through approaches such as network pharmacology. This will provide a theoretical basis for its clinical application. Moreover, traditional medicinal knowledge holds that the seeds and roots of *C. ternatea* possess toxicity, though this lacks direct experimental data to substantiate it. Further systematic pharmacodynamic and toxicological studies are required. Clarifying its toxicity and safety profile will provide comprehensive and reliable scientific evidence for the integrated development and utilization of *C. ternatea*.

*C. ternatea* is widely distributed in southern China, including Guangdong, Yunnan, and Zhejiang provinces. Due to significant variations in growing conditions and varieties across different regions, the quality is inconsistent. Therefore, it is necessary to conduct botanical verification and resource surveys to clarify the botanical origin, suitable growing regions, and superior cultivars of *C. ternatea*. *C. ternatea* possesses extensive potential for application across the food, pharmaceutical, cosmetics, and health supplement sectors. In China's tropical and subtropical regions, *C. ternatea* thrives under favourable conditions, presenting promising prospects for its cultivation and development as an economic crop. However, the current product conversion rate for *C. ternatea* in China remains low, with applications largely confined to beverages or ornamental purposes. Future development may focus on creating pharmaceuticals, skincare products, and additives primarily based on anthocyanins. This will enable the high-value utilization of *C. ternatea* resources.

In the course of developing and utilizing *C. ternatea*, refining its quality standards is of paramount importance. At present, China's quality standards system for *C. ternatea* remains incomplete, necessitating the establishment of a scientifically rigorous quality standards framework to advance in-depth research into this crop. This will provide a standardized basis for subsequent resource development and utilization.

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## Author Contributions

Yi Wang: Data curation, Formal analysis, Writing—original draft; Huan Chen: Data curation; Pucheng Feng: Data curation; Deyun Wang: Data curation; Xiaoquan Du: Funding acquisition, Supervision, Writing—review & editing.

## Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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