

PHYTOCHEMICAL AND PHARMACOLOGICAL ASPECTS OF *CLITORIA TERNATEA*- A REVIEW

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ABSTRACT

Medicinal and aromatic plants have been used over the ages for its potency and minimal side effects. Due to this, the exploration is at its highest peak. Seeing this phenomenon the climbing plant *Clitoria ternatea* (CT) belonging to the Fabaceae family and commonly known as 'Butterfly pea' and *Shankpushpi*, has been taken up which is used in Traditional Ayurvedic Medicine, because of its varied uses over centuries as a memory enhancer, nootropic, antistress, anxiolytic, antidepressant, anticonvulsant, tranquilizing and sedative agent. A wide range of secondary metabolites including triterpenoids, flavonol glycosides, anthocyanins and steroids has been isolated from *Clitoria ternatea* Linn. Its extracts possess a wide range of pharmacological activities including antimicrobial, antipyretic, anti-inflammatory, analgesic, diuretic, local anaesthetic, antidiabetic, insecticidal, blood platelet aggregation-inhibiting and for use as a vascular smooth muscle relaxing properties. This plant has a long use in traditional Ayurvedic medicine for several diseases and the scientific studies has reconfirmed those with modern relevance. The plant contains many active constituents like alkaloids, glucosides, flavonoids, saponins, tannins, carbohydrates etc. This review is an effort to explore the phytochemical constituents and pharmacological studies of CT, which have been in clinical use in the Ayurvedic system of medicine along with a critical appraisal of its future ethno pharmacological potential in view of many recent findings of importance on this well-known plant species.

Keywords: *Clitoria ternatea*, Phytochemical studies, Pharmacological activity, Medicinal uses.

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INTRODUCTION

Clitoria ternatea, commonly known as Asian pigeon wings,^[1] blue bellvine, blue pea, butterfly pea, cordofan pea and darwin pea,^[2] is a plant species belonging to the Fabaceae family. (Synonyms: *Clitoris principissae*.) It is a perennial herbaceous plant, with elliptic, obtuse leaves. It grows as a vine or creeper, doing well in moist, neutral soil. The most striking feature about this plant is the colour of its flowers, a vivid deep blue; solitary, with light yellow markings. They are about 4 cm (1.6 in) long by 3 cm (1.2 in) wide. Some varieties yield white flowers. The fruits are 5–7 cm (2.0–2.8 in) long, flat pods with six to ten seeds in each pod. They are edible when tender. It is grown as an ornamental plant and as a revegetation species (e.g., in coal mines in Australia), requiring little care when cultivated. Being a leguminous plant its roots form a symbiotic association with soil bacteria known as rhizobium which fixes atmospheric Nitrogen into a plant-usable form (a process called nitrogen-fixing), therefore, this plant is also used to improve soil quality through the decomposition of nitrogen-rich plant material.^[3] Chemical compounds isolated from *C. ternatea* include various triterpenoids, glycosides, flavonoids, anthocyanidins and sterols.^[4] Clitoides, the cyclic peptides have

been isolated from the heat-stable fraction of *C. ternatea* extract.^[5] The plant *Clitoria ternatea* is traditionally used for food colouring, stress, infertility and gonorrhoea. The plant has been widely used in Ayurveda. Pharmacologically it is an anxiolytic, anti-inflammatory, analgesic, anti-microbial and anti-carcinogenic. It is also CNS Depressant, nephroprotective and has anti-Stress activities. Generally, *Clitoria ternatea* has larvicidal activities, proteolytic activities, antihelminthic activities, antihyperglycemic activity, diuretic activity, antioxidant activity, antihistaminic activity and treat goiter.^[6] Phytochemistry and functions of different parts of *Clitoria ternatea* were presented in Table 1 and Table 2. Picture of *Clitoria ternatea* was presented in Figure 1.

Scientific Classification

Kingdom: Plantae

Order: Fabales

Family: Fabaceae

Chakraborty *et al.*: Pharmacological review of *Clitoria ternatea* Linn.

Genus: *Clitoria*

Species: *C. ternatea*

Binomial name: *Clitoria ternatea* L

Synonyms: *Clitoria principissae*

PHYTOCHEMICAL CONSTITUENTS

Flower contains major flavonol glycosides, 3-O- (2"-O-alpha-rhamnosyl-6"-O-malonyl)-beta-glucoside, 3-O-(6"-O-alpha-rhamnosyl-6"-O-malonyl)-beta-glucoside and 3-O-(2"-6"-di-O-alpha-rhamnosyl)-beta-glucoside of kaemferol (I), quercetin (II) and myricetin (III) were isolated from the petals. Minor delphinidin glycosides, 3-O-b-glucoside, 3-O-(2"-O-a-rhamnosyl)-b-glucoside, 3-O-(2"-O-a-rhamnosyl-6"-O-malonyl)-b-glucoside of delphinidin. Eight anthocyanins (ternatins C1, C2, C3, C4, C5 and D3, and preternatins A3 and C4) were also isolated from the flowers. Six ternatins from the flowers were partly characterized as highly acylated delphinidin derivatives. Deacylternatin was determined as delphinidin-3, 3', 5'-tri-O-b-D glucopyranoside. White petals do not contain anthocyanins. There are low levels of condensed tannins (0.2-4.8 mg catechin/g) and protein precipitable polyphenols (0.16-0.77 mg tannic acid/g) in the raw mature seeds. Root bark contains Tannin and Resin Taraxerol (VIII) and tataraxerone. Roots show the presence of alkaloids, flavonoids, saponins, tannins, carbohydrates,

proteins, resins, starch, taraxerol and taraxerone. Seeds contain a highly basic small protein named finotin. 8 contains fixed oil. Cinnamic acid, palmitic (IV), stearic (V), oleic (VI), linoleic (VII), linoleic acids and an anthoxanthin Glucoside.^[14]

TRADITIONAL USES

Butterfly-pea flower tea is a caffeine-free herbal tea, or tisane, a beverage made from a decoction or infusion of the leaves of the *Clitoria ternatea* plant and dried lemongrass. Butterfly pea flower tea retains many of the medicinal properties of the *Clitoria ternatea* as well as extracting the deep blue colour of the petals that have made the plant a popular dye for centuries. One of the aspects of the tea is the fact that the liquid changes colour based on the pH level of the substance added to it, for instance, adding lemon juice to the tea will turn it purple.^[15] Chinese have also used this plant in medical preparations for curing ailments afflicting reproductive organs.^[16] *Clitoria ternatea* is known as aparajita in Bengali which is used as a well known ayurvedic medicine. All the part of the herb (leaf, root, shoot) is used as medicine. In traditional Ayurvedic medicine, it has been used for centuries as a memory enhancer, nootropic, antistress, anxiolytic, antidepressant, anticonvulsant, tranquilizing and sedative agent^[4]. It is also used in neurological disorders.^[17]

Table 1: Phytochemical composition and functions of different parts of *Clitoria ternatea*

Plant parts	Phytochemicals	Functions
Flower	Saponin, Tannins, Alkaloids, Glycosides, Phytosterols, Carbohydrates	Anti-inflammatory, analgesic, Ethanol extract is used as antidiabetic ^{[7][8]}
Leaf	Alkaloids, reducing sugars, flavonoids, steroids, glycosides	Prevention of neurodegenerative diseases and diabetes mellitus and Effectively controls excessive sweating ^{[9][10]} .
Root	1,1-diphenyl-2-picrylhydrazyl (DPPH)	It is used as an antioxidant and the root bark is diuretic and laxative; a decoction is given as a demulcent in the irritation of the bladder and urethra ^{[11][12]} .
Seed	The seeds contain nucleoprotein with its amino-acid sequence similar to insulin, delphinidin-3,3,5-triglucoside, essential amino-acids, pentosan, water-soluble mucilage, adenosine, an anthoxanthin glucoside, greenish yellow fixed oil a phenol glycoside, 3,5,7,4-tetrahydroxy-flavone-3-rhamnoglycoside, an alkaloid, ethyl D-galactopyranoside, p-hydroxycinnamic acid polypeptide, a highly basic protein-finotin, a bitter acid resin, tannic acid, 6% ash and a toxic alkaloid	Seeds are cathartic, purgative and aperients. They are used in swollen joints, dropsy and enlargement of abdominal viscera. ^[13]

Table 2: Functions of various parts of *Clitoria ternatea*^{[18][19][20]}

Part	Functions
Flower and Roots	As a colouring agent used in dietary products.
Whole plant	In the treatment of Nootropic, Anxiolytic, antidepressant, anticonvulsant and antistress activity. Also used in treating sexual ailments such as fertility and gonorrhoea. Given in cases of heat stable function.

PHARMACOLOGICAL ACTIVITY

Antioxidant and cytotoxic activity

An antioxidant activity of the butterfly pea extracts and the eye gel by spectrophotometrically method was carried out and it was observed that aqueous extract of *C. Ternatea* possess stronger antioxidant activity, as assayed by the reduction of 2, 2-diphenyl-1-picrylhydrazyl (DPPH), than that of ethanol extracts. The IC₅₀ values were 1 mg/mL and 4 mg/mL, respectively. As antioxidant activity is often attributed to phenolic compounds within plants the total phenolic content within the aqueous extract and gel were measured. As the water extract had the stronger antioxidant activity it was used in the formulation of an eye gel and it was found that the inclusion of the extract into the gel base did not significantly reduce the antioxidant activity of the extract. At 0.25 mg/mL the percentage inhibition of DPPH reduction was 32% for the extract and 28% for the gel + extract; at 0.5 mg/mL the percentage inhibition for both the extract and for the gel + extract was 34%. However, the inhibition caused by the gel containing extract was significantly less than that of a commercial eye anti wrinkle firming cream. A 0.1 mg/mL sample of commercial eye cream produced 93% inhibition of DPPH reduction compared with only 9% inhibition for 0.1 mg/mL of the gel + extract. This suggests that while the extract maintains its antioxidant activity within the gel base, the concentration required to do so is higher than that of a commercial product.^[20]

Ethanol extract of aerial parts of *C. Ternatea* (CT) were screened for anticonvulsant activity using maximum electroshock seizure (MES) test and, pentylenetetrazol (PTZ) test in rats. At the dose of 230 and 460 mg/kg, no significant effects were observed in both tests. The anti stress activity of a methanolic extract of aerial part of CT was evaluated using cold-restraint stress-induced ulcers, lithium-induced head twitches, clonidine-induced hypothermia, and sodium-nitrite-induced respiratory arrest and, haloperidol-induced catalepsy in rat and mice. The treatment with CT (100,200, and 400mg/kg) significantly reduced the ulcer index. CT decreased ulcer index dose-dependently and showed anti stress activity. CT (100mg/kg) significantly reduced the number of head twitches. CT reduced the head twitches significantly, and at the same dose exhibited increased IR in EPM, suggesting a link between cognitive improvements and decreased serotonergic transmission. CT (100mg/kg po) per se was without any effect on the rectal temperature and CT did not significantly alter clonidine-induced hypothermia. CT failed to reverse clonidine-induced hypothermia, indicating that noradrenergic mechanism was not involved in the central effects of CT. The effect of CT (100 mg/kg po) was not significant in the mice treated with sodium nitrite. CT failed to decrease the effect of sodium nitrite. Oral administration of CT (100 mg/kg potentiates haloperidol-induced catalepsy only up to 45min which is not significant.^[21]

Methanolic extract of the aerial parts of *C. Ternatea* (CT) was screened using PTZ- and maximum electroshock (MES)-induced seizures in mice at the dose of 100mg/kg and it was found that CT significantly delayed the onset of convulsions in PTZ-induced convulsions and also delayed the duration of tonic hind limb extension in MES-induced convulsions. These results suggest that CT may be useful in the treatment of seizures.^[18]

Antioxidant property of methanolic extract (ME) of *C. ternatea* leaf was evaluated by employing an *in vitro* antioxidant assay and the result showed that the number of total phenolics and flavonoids were estimated to be 358.99 ± 6.21 mg/g gallic acid equivalent and 123.75 ± 2.84 mg/g catechin equivalent, respectively. The antioxidant activity of *C. ternatea* leaf extract was 67.85% at a

concentration of 1 mg/mL and was also concentration dependent, with an IC₅₀ value of 420µg/mL.^[22]

A study of ethanolic extract of *Clitoria ternatea* proved that the plant possess cytotoxic and antioxidant activities. The extract showed potent cytotoxic activity in trypan blue dye exclusion method using DLA cell lines with EC₅₀ value of 305µg/ml and exhibited a dose-dependent decrease in cell count for all the concentrations tested. The antioxidant activity was evaluated by DPPH free radical method. The extract exhibited potent antioxidant activity with an EC₅₀ of 36.5µg/ml. There was a dose-dependent increase in the percentage of antioxidant activity for all concentrations tested.^[23]

In-vitro cytotoxic effects of petroleum ether and ethanolic extracts of flowers of *Clitoria ternatea* using trypan blue dye exclusion method was evaluated. The various concentration of plant extracts used were 10, 50, 100, 200, 500 µg/ml and control (without extract). For both, the extracts decrease in cell count was observed with increase in the concentration of the extract. There was a dose-dependent increase in cytotoxic activity for all the concentrations tested. For petroleum ether extract the concentration of 10 µg/ml showed a reduction of 8 % and 100% reduction observed at 500µg/ml. In case of ethanolic extract at 10 µg/ml concentrations 1.33 % reduction was observed and at 500µg/ml 80 % reduction in cell count was observed.^[24]

Clitoria ternatea was screened for anticancer effects against Dalton's Lymphoma (DLA) bearing mice. Tumour was induced in mice by the intraperitoneal injection of DLA cells and after 24 hours of tumour inoculation, the methanol extract of *Clitoria ternatea* (MECT) was administered at doses of 100 and 200mg/kg body weight for 14 consecutive days. The effect of MECT was assessed using *in vitro* cytotoxicity, survival time, peritoneal cell count, haematological studies and antioxidant parameters. Treatment with MECT led to a decrease in tumour volume, packed cell volume and viable count. It also increased the non-viable cell count and mean survival time. Haematological profile reverted to more or less normal levels in the treated group. The results suggest that MECT exhibit p values <0.05 was concern significant antitumor effects in DLA bearing mice.^[25]

Antioxidant activity of *in vitro* grown plants *Clitoria ternatea* was evaluated using DPPH free radical scavenging assay and it was found that ethanolic extract of *in vitro* grown *Clitoria ternatea* significantly inhibited the DPPH free radicals at the concentration ranging from 25-600µg mL⁻¹. It showed the highest inhibition of 67% at 600µg mL⁻¹ equal to *in vivo* grown plant 70% at 600µg mL⁻¹. The *in vitro* multiplication ensures germplasm conservation of rare, endangered, aromatic medicinal plant while intrinsic natural antioxidants level could be harnessed for a cure of diseases.^[26]

The antioxidant activity and protective effect of *Clitoria ternatea* flower extract on testicular damage induced by ketoconazole, 2,2-diphenyl-1-picrylhydrazyl (DPPH) and ferric reducing antioxidant power (FRAP) assay methods showed that the *Clitoria ternatea* (CT) flower extracts had capabilities for DPPH scavenging and high reducing power. At 100 mg/kg BW, the extract had no toxic effects on the male reproductive system. Significantly, in CT+KET groups, CT flower extracts (50 and 100 mg/kg BW) alleviated the reduction of reproductive organ weight parameters, testosterone levels, and sperm concentration. In addition, CT flower extracts gave protection from testicular damage in KET-induced rats. Moreover, in the CT100+KET group, CT flower extracts significantly enhanced the expression of a testicular 50-kDa tyrosine phosphorylated protein compared with that of other groups.^[27]

Anti Diabetic activity

Anti diabetic activity of ethanolic extract was evaluated in rats. Rats fed with ethanolic extracts of flowers for 3 weeks significantly lowered serum sugar level in experimentally induced diabetes due to inhibition of the galactosidase and glucosidase activities but no inhibition of fructosidase activity was observed.^[28]

The hypoglycemic effects of methanol, water, and petroleum ether and chloroform extract of *Clitoria ternatea* leaves were evaluated in Streptozotocin-induced diabetic rats for acute and subacute effects. The extract of *Clitoria ternatea* (200 and 400 mg/kg) significantly reduced the blood glucose level in Streptozotocin-induced diabetic rats. 400mg/kg possessed significant hypoglycemic effect, 200 mg/kg also decreased glucose level but not as 400mg/kg. The result of the acute effect of the methanol extract showed that 200 and 400 mg/kg exerted a very similar effect, but at the initial stage at the 30 min, 200mg/kg showed a fine decrease in blood glucose level. Subacute activity showed that on the long-term use of extract the dose 200 mg/kg is much better to control the blood glucose level than the 400 mg/kg dose.^{[29] [30]} Methanolic extract of *Clitoria ternatea* leaves (200 and 400 mg/kg) when evaluated for hypoglycaemic effects by alloxan-induced diabetic rats showed that the extract of *Clitoria ternatea* significantly (P<0.001) reduced blood glucose level in alloxan-induced diabetic rats twelve hours after administration.^{[29] [31]}

The hypoglycemic effects of the aqueous extract of *Clitoria ternatea* leaves and flowers (50-500mg/kg) by alloxan-induced diabetes were studied in rats. The aqueous extracts of *Clitoria ternatea* leaves and flowers (400 mg/kg body weight) significantly (P <0.05) reduced serum glucose, glycosylated haemoglobin and the activities of gluconeogenic enzyme, glucose-6- phosphatase, but increased serum insulin, liver and skeletal muscle glycogen and the activity of the glycolytic enzyme, glucokinase. For all the biochemical tests performed, the leaf extract-treated rat showed essentially the same profile as those treated with the flower extract.^{[32] [33]}

A study revealed the pancreatic regeneration potential of different fractions of the ethanolic extract of the aerial parts of *Clitoria ternatea* L. The anti diabetic and anti hyperlipidemic potential was evaluated in streptozotocin-induced diabetic rats and correlated with its *in vivo* and *in vitro* antioxidant activity. The extract and its fractions were initially screened for acute and sub-chronic antidiabetic activity in the dose range of 100- 200 mg/kg. The most potent extract and fractions were further evaluated for pancreatic β -cells regeneration activity along with the antioxidant and anti hyperlipidemic activity. The most significant pancreatic regeneration activity, anti diabetic and anti hyperlipidemic activity was shown by ethanolic extract and butanol soluble fraction at a dose level of 200 mg/kg.^[34]

The hypoglycemic effects of methanol, water, petroleum ether and chloroform extract of *Clitoria ternatea* leaves in Streptozotocin-induced diabetic rats for acute and subacute effects were studied. The extract of *Clitoria ternatea* (200 and 400 mg/kg) significantly reduced blood glucose level in streptozotocin-induced diabetic rats. 400mg/kg possessed significant hypoglycemic effect, 200 mg/kg also decreased glucose level but not as 400mg/kg. The result of an acute effect of the methanol extract showed that 200 and 400 mg/kg exerted a very similar effect, but at the initial stage at the 30 min, 200mg/kg showed a fine decrease in blood glucose level. Subacute activity showed that on the long-term use of extract the dose 200 mg/kg is much better to control the blood glucose level than the 400 mg/kg dose.^[30]

In alloxan-induced diabetic rats, the effect of aqueous extract of *C. ternatea* leaves and flowers on serum glucose, glycosylated haemoglobin, insulin, total cholesterol, triglycerides, HDL-cholesterol, protein, urea, creatinine were examined in control and

extract treated diabetic rats. Glycogen was examined both in the liver and skeletal muscles of control and extract treated diabetic rats, whereas, the activity of glycolytic enzyme glucokinase and gluconeogenic enzyme glucose-6-phosphatase was examined in the liver. Oral administration of aqueous extract of *C. ternatea* leaves (400 mg/kg body weight) and flowers (400 mg/kg body weight) for 84 days significantly reduced serum glucose, glycosylated hemoglobin, total cholesterol, triglycerides, urea, creatinine and the activity of gluconeogenic enzyme glucose-6-phosphatase, but increased serum insulin, HDL-cholesterol, protein, liver and skeletal muscle glycogen content and the activity of glycolytic enzyme glucokinase. For all the above biochemical parameters investigated, *C. ternatea* leaves treated rat showed a little better activity than *C. ternatea* flowers treated diabetic rats. The study revealed that the *C. ternatea* leaves and flowers extract possess anti hyperglycaemic and anti hyperlipidaemic effects and consequently may alleviate liver and renal damage associated with alloxan-induced diabetes mellitus in rats.^[33]

Anti-hyperlipidemic effect of *Clitoria ternatea* L. and *Vigna mungo* L. (Fabaceae) on experimentally induced hyperlipidemia in rats by poloxamer 407-induced acute hyperlipidemia and diet-induced hyperlipidemia models was studied and results showed that the hydroalcoholic extract of the roots and seeds of *C. ternatea* and the hydroalcoholic extract of the seeds of *V. mungo* resulted in a significant ($p < 0.05$) reduction of serum total cholesterol, triglycerides, very low-density lipoprotein cholesterol, and low-density lipoprotein cholesterol levels. The atherogenic index and the high-density lipoprotein (HDL)/ low-density lipoprotein (LDL) ratio were also normalized after treatment in diet-induced hyperlipidemic rats.^[35]

Local Anaesthetic effect

The local anaesthetic effect of an alcoholic extract of *Clitoria ternatea* aerial part using corneal anaesthesia in rabbits and, plexus anaesthesia in frogs was studied. 10% solution of alcoholic extract of *Clitoria ternatea* (CT) aerial part produced abolition of the foot withdrawal reflex in frogs but failed to produce any surface anaesthetic effect on rabbit cornea. Alcoholic extract of CT aerial part was almost as effective as xylocaine in inducing local anaesthesia.^[21]

Gastrointestinal effect

The antiulcer potential of aqueous and ethanolic extracts of *Clitoria ternatea* was evaluated in different experimentally induced ulcer models in rats. Ethanolic extract (200 and 400 mg/kg) and aqueous extract (200 and 400 mg/kg) of whole plant were examined in pylorus ligation and indomethacin-induced gastric ulcer in rats. Various parameters like volume of gastric acid secretion, pH, total acidity, ulcer index and antioxidant parameters were determined and compared between extracts, standard and vehicle control group following ulcer induction. Among different dose of alcoholic extract, high dose showed significant antiulcer activity in pylorus ligation and indomethacin-induced ulceration.^[36]

Anti-inflammatory, Analgesic and Antipyretic activity

Methanolic extract of *Clitoria ternatea* roots when given by oral route to rats was found to inhibit both the rat paw oedema caused by carrageenin and vascular permeability induced by acetic acid in rats thereby showing potent anti-inflammatory, analgesic and antipyretic activity. The extract of root of *C. ternatea* exhibited a significant inhibition of oedema induced by carrageenan by 21.6% and 31.8%, respectively, at 200 and 400 mg/kg. The dose of 400 mg/kg exhibits an inhibition comparable to that of 20 mg/kg of diclofenac. Furthermore, the extract reduced the intensity of peritoneal inflammation by 35.9 and 55.1% as observed in the

reduction of Evan blue dye leakage induced by acetic acid in rats compared with that of diclofenac as the standard drug. We can conclude that the methanol extract of *C. ternatea* possesses significant anti-inflammatory, analgesic and anti pyretic activity.^[37] *Clitoria ternatea* showed antipyretic activity by causing a reduction in yeast-induced fever in rats. The extract markedly reduced the number of writhings at both tested doses by 50.1 and 63.8% compared to the reduction of 70.9% induced by 150 mg/kg of aspirin. From the overall results, we can conclude that the methanol extract of *C. ternatea* possesses significant analgesic and antipyretic activities^[37].

A study of methanolic extract of blue-flowered variety of *Clitoria ternatea* root (MECTR), for its antipyretic potential on normal body temperature and yeast-induced pyrexia in albino rats was performed. Yeast suspension (10ml/kg) increased rectal temperature after 19 hours of subcutaneous injection. The extract, at doses of (200,300 and 400 mg/kg), produced a significant reduction in normal body temperature and yeast-provoked elevated temperature in a dose-dependent manner. The effect extended up to 5 hours after the drug administration. The anti-pyretic effect of the extract was comparable to that of paracetamol (150 mg/kg).^[38]

Antihistamine activity

Antihistaminic activity of *Clitoria ternatea* L. roots by Clonidine-induced catalepsy in mice and Haloperidol-Induced Catalepsy model was analyzed. Clonidine, a α_2 adrenoreceptor agonist induces dose-dependent catalepsy in mice, which was inhibited by histamine H1 receptor antagonists but not by H2 receptor antagonist. Clonidine releases histamine from mast cells which is responsible for different asthmatic conditions. Finding of investigation showed that chlorpheniramine maleate (CPM) and extract of *Clitoria ternatea* root (ECTR) inhibit clonidine induced catalepsy significantly $P < 0.001$ when compared to control group, while CPM and ECTR fail to inhibit haloperidol-induced catalepsy. The present study concludes that ECTR possesses antihistaminic activity.^[39]

Effect on learning and memory

The effects of *Clitoria ternatea* (CT) aqueous root extract on learning and memory in rat pups (7 days old) using open field behaviour test, spontaneous alternation test, rewarded alternation test and passive avoidance test were observed. The results of this study showed that the oral treatment of CT roots extracts at different doses significantly enhanced memory in rats. CT aqueous root extract for learning and memory improvement using open field behaviour test, passive avoidance test and, spatial learning test (T-maze test) in neonatal rat pups (7days old). Neonatal rat pups were incubated during growth spurt period at the dose of 50 and 100mg/kg of aqueous root extract for 30 days. CT root extract had memory enhancing properties which had little or no effect on the general motor activity but showed improved retention and spatial learning performance at both time points of behavioural tests. This memory enhancing property was marked in neonatal rats (which were in their growth spurt period) treated with CT 100mg/kg bodyweight for 30 days. Thus it appears that treatment with CT extract results in permanent change in the brain which was responsible for the improved learning and memory.^[40]

Antidepressant, tranquilizing and sedative activity

In a study of gross behavioural effect following the administration of an alcoholic extract of CT aerial part in a dose range of 1–2 g/kg. Post drug observations were made at intervals of 30 min, 3 and 6 h. The results indicate that like chlorpromazine, it possesses prominent CNS effects, characterized by tranquilizing properties

such as dose-dependent inhibition of alertness, diminution of spontaneous motor activity and increased sedation. Loss of righting reflex was observed in some mice with this extracts and the animals responded well to the acoustic, tactile and nociceptive stimuli were reduced. The same extract showed inhibition of the conditioned avoidance response. No catalepsy was observed even at the highest dose of extract used. Chlorpromazine 10 mg/kg, exhibited marked reflex and moderate catalepsy. It was reported that this extract of aerial part of CT potentiates the barbiturate-induced sleeping time in rats in a dose-dependent manner which was comparable to the standard drug chlorpromazine.^[21]

Antidepressant activity of methanolic extract of aerial part of *C. ternatea* (CT) at the doses of 100 and 400mg/kg using tail suspension test was observed in a study. Oral administration of CT significantly reduced the duration of immobility. CT decreased total duration of immobility and did not produce sedation and behavioural toxicity but improved cognitive abilities. Tranquilizing property of alcoholic extract of aerial part of CT was evaluated in rats using conditioned avoidance response test. Oral treatment of alcoholic extract at the dose of 230 mg/kg did not influence conditioned avoidance response in rats whereas a very high dose of 460 mg/kg inhibited conditioned avoidance response in 66% rats without affecting the unconditioned response. The pharmacological relevance of such a high doses remains doubtful.^[18]

Anticonvulsant and antistress activity of CT

The anticonvulsant activity of a methanol extract from the aerial parts of *C. ternatea* (CT) was screened using PTZ- and maximum electroshock (MES)-induced seizures in mice at the dose of 100mg/kg. CT significantly delayed the onset of convulsions in PTZ-induced convulsions and also delayed the duration of tonic hind limb extension in MES-induced convulsions. These results suggest that CT may be useful in the treatment of seizure.^[18]

The anticonvulsant activity of an ethanolic extract of aerial parts of *C. ternatea* using maximum electroshock seizure (MES) test and, pentylentetrazol (PTZ) test in rats were observed at the dose of 230 and 460 mg/kg no significant effects were observed in both tests.^[21]

It was estimated that the *C. ternatea* root extract enhanced ACh content significantly in the hippocampi when analyzed by fluorimetric method in neonatal rats from 52.79±12.36 to 68.83±9.87 nmol/g tissue, young adults rats from 33.9±6.92 to 88.89±18.29 nmol/g tissue. Hippocampal ACh content was found to be significantly less in 90-day-old control rats as compared to 37-day-old control rats: (33.9±6.92 vs. 52.79±12.36 nmol/g tissue). On the contrary, hippocampal ACh content was found to be higher in 90-day-old CTR treated rats than in 37-day-old CTR treated rats 88.89±18.29 tissue vs. 68.83±9.87 nmol/g tissue and result were expressed as mean±S.D., were statistically compared by Student's *t*-test. Values of $P < 0.05$ were considered statistically significant.^[41]

Anti Asthmatic activity

Anti asthmatic activity of *Clitoria ternatea* root's ethanol extract (ECTR) was evaluated for preliminary phytochemical screening, acute toxicity studies and antiasthmatic activity using milk induced leucocytosis and eosinophilia in mice, egg albumin induced mast cell degranulation in rats and passive cutaneous anaphylaxis in rats result showed that the LD₅₀ of ECTR is more than 1300 mg/kg. ECTR significantly decreases milk induced leucocytosis and eosinophilia protects egg albumin induced degranulation of mast cells in mice and inhibits area of blue dye leakage in passive cutaneous anaphylaxis in rats. Phytochemical studies observed the presence of steroids, saponin, flavonoids, and glycosides^[39].

Hepatoprotective activity

Hepatoprotective effect against paracetamol-induced liver toxicity in mice of methanolic extract (ME) of *C. ternatea* leaf and activity was measured by monitoring the levels of aspartate aminotransferase (AST), alanine aminotransferase (ALT) and bilirubin along with histopathological analysis. The results of the paracetamol-induced liver toxicity experiments showed that mice treated with the ME of *C. Ternatea* leaf (200 mg/kg) showed a significant decrease in ALT, AST, and bilirubin levels, which were all elevated in the paracetamol group ($p < 0.01$). *C. ternatea* leaf extract therapy also protective effects against histopathological alterations.^[22]

Wound healing effect

The wound healing activity of *Clitoria ternatea* seed and root extracts was investigated using excision, incision and dead-space models in rats. *Clitoria ternatea* seed and root extract significantly improved wound healing in excision, incision and dead-space models when administered orally by gavage as well as applied topically as an ointment. These effects were comparable to that of cotrimoxazole ointment. The finding of the study also showed that *Clitoria ternatea* affected all three phases: inflammatory, proliferative and remodelling phases of wound healing.^[42]

The wound healing potential of standardized *Clitoria ternatea* leaf extract in terms of different enzymatic models, which are mostly associated with skin wound, was evaluated. The methanol extract and fractions were screened for its hyaluronidase, elastase, and matrix metalloproteinase-1 (MMP-1) inhibitory activity compared with standard oleonic acid. The activity was rationalized through reverse-phase high-performance liquid chromatography (RP-HPLC) standardization of the extract and fractions with respect to its isolated biomarker taraxerol (yield 5.27% w/w). The extract showed significant ($P < 0.001$) hyaluronidase (IC₅₀) 18.08 ± 0.46 µg/ml and MMP-1 ($P < 0.05$) inhibition, but the elastase inhibition was insignificant (IC₅₀ 42.68 ± 0.46 µg/ml). Among the fractions, ethyl acetate fraction showed significant ($P < 0.001$) inhibition of hyaluronidase (IC₅₀: 28.01 ± 0.48 µg/ml) and MMP-1 ($P < 0.01$). The HPLC analysis revealed that the extract and the ethyl acetate fraction are enriched with taraxerol (5.32% w/w and 4.55% w/w, respectively).^[43]

CONCLUSION

Clitoria ternatea is considered to be a valuable plant in both modern drug development areas because of its versatile medicinal uses. Other than medicinal, it has many other uses in our day to day life as it is also used as substituent for other drug possessing the same pharmacological action. Thus this paper reviewed *Clitoria ternatea* as promising medicinal plant with wide range of pharmacological activities which could be utilized in several medical applications because of its effectiveness and safety.

CONFLICT OF INTEREST

The authors have no conflict of interest.

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