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The Multifaceted *Clitoria ternatea* (Aparajita): A Review of Its Phytochemistry, Medicinal Uses and Commercial Applications

Tamanna [a], Amanpreet Kaur [a], Navdeep Singh [a] and Richa Shri [a++*]

[a] Department of Pharmaceutical Sciences and Drug Research, Punjabi University, Patiala-147002, India.

Authors' contributions

This work was carried out in collaboration among all authors. Author RS designed the study and checked the manuscript. The authors – Tamanna, AK and NS did exhaustive literature searches and critically combined the information. Author Tamanna wrote the first draft of the manuscript and all gave inputs for the final draft. All authors read and approved the final manuscript

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Review Article

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ABSTRACT

Clitoria ternatea Linn., (aparajita/shankapushpi; family Fabaceae), is a traditional medicinal plant with diverse applications - both medicinal and commercial. It is a perennial twinning herb with prominent flowers. The multifaceted plant is native to tropical Asia. The aim of this review is to provide in-depth information on the phytochemistry along with commercial and medicinal uses of *C.*

[++] *Professor;*
**Corresponding author: E-mail: richashri@pbi.ac.in;*

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ternatea. Exhaustive review of available literature was carried out to compile and critically evaluate scientific information available on the plant. According to available literature, the plant possesses diverse health benefits. Traditionally it is used as an antidote for snake and scorpion bite, memory enhancer and anxiolytic agent and it shows various pharmacological activities that includes antidepressant, antioxidant, anti-inflammatory, anti-pyretic, analgesic etc. The activities are attributed to the presence of varied constituents predominantly the unique acylated anthocyanins – ternatins, cyclotides, phenolic compounds etc. Commercially it is valued as a natural dye and food colorant because of the acylated anthocyanins in it. This plant has marked antioxidant and antiaging properties and hence it is gaining popularity in formulating cosmetics and cosmeceuticals. It is also used for protecting crops in agrotechnology. This review highlights the numerous medicinal properties, commercial uses, as well as its phytochemical investigation prove multifaceted potential of this plant. Further directions for developing the plant and its products as effective and stable medicine, nutraceutical and cosmeceuticals are also suggested.

Keywords: Acylated anthocyanins; Clitoria ternatea; cosmetics; food colorant; medicinal uses; shankapushpi; traditional medicine.

1. INTRODUCTION

Globally medicinal plants are employed to impart health and to cure several illnesses. Plant products are used in both modern and traditional systems of medicine. The Ayurvedic medicinal system is notable for the impact of its "Medhya Rasayana" collection of herbal remedies on the nervous system. "Medhya drugs" are described as having the capacity to improve cognition in Ayurvedic literature.

Acorus calamus, Areca catechu, Celastrus panniculatus, Centella asiatica, Clitoria ternatea, Tinospora cordifolia, and *Withania somnifera* a few examples said to influence the neurological system. There is greater emphasis in the current time to generate evidence to support traditional claims hence many plants are being investigated in detail to assess their medicinal potential and to identify the active ingredients.

One important “Medhya Rasayana”- *Clitoria ternatea* (commonly called aparajita/shankapushpi; family Fabaceae). This plant has been examined from various perspectives showing its phytochemistry, pharmacological as well as commercial uses. It is a perennial climber. This ornamental plant is valued due to its attractive colour of the flower [1]. It is a self-pollinated plant with diploid chromosome number (2n=16) [2]. Because of the presence of high protein content, it is also used as fodder for the cattle. It is a drought tolerant plant [3].

Distributed in many tropical countries like in Caribbean, India, Madagascar, Philippines, South and Central America, and other tropical Asian countries, Two types of varieties of this flower, one is white flower, and blue flower.

The aim of this review article is to highlight the commercial and medicinal applications of *C. ternatea.*

2. TAXONOMIC CLASSIFICATION

Some of the synonyms of *Clitoria ternatea* are presented in Table 1.

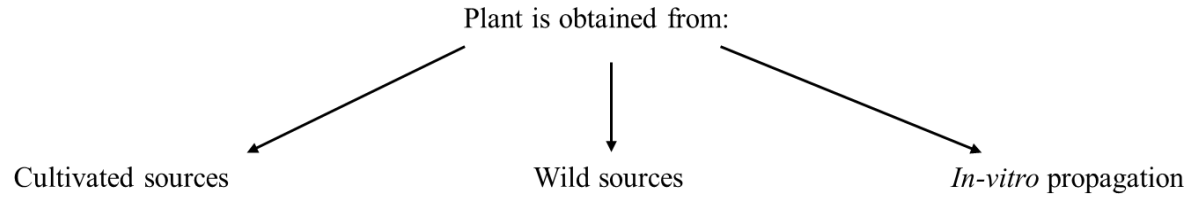
Table 1. Synonyms of *C. ternatea*

Language	Synonyms
Brazilian	Cunha
Chinese	Lan hu die
Hindi	Koyala
Indonesian	Bunga biru, tembang telang
Malaysia	Telang
Philippines	Pokindang
Portuguese	Fulacriquacunha˜ fula criqua
Sanskrit	Shankapushpi, Aparajita, Saukarnika, Supuspi, Vishnukranta
Spanish	Clitoria azul
Sudan	Butterfly pea, Kordofan pea
Thai	Dangchan
Turkish	Mavi kelebek sarmasıgı

References: Mukherjee et al.*,[4]; Jayaraj* et al.*, [5].*

3. PLANT CULTIVATION

It is a perennial ornamental plant which can be cultivated in gardens and grows wild as well.



The plant needs some requirements for growth which are presented in Table 2.

Table 2. Requirements for growth of the plant

Requirements for growth	
Altitude	0-1600 metres
Lifecycle of flower	Flowering takes 4 to 5 weeks
pH	5.5 to 8.9
Season	Perennial
Soil Type	Variety of soils including calcareous soils
Spacing	15 - 30 cm (slight row gap is preferred)
Sowing depth (damp soils)	2.5 - 6.5 cm
Sunlight/Shade	Prefer full sunlight, but occasionally partially shaded areas
Temperature Range	19-28°C

References: Gomez and Kalamani, [1]; Chahal et al*., 2010; Multisona* et al*., [6]; Patel and Mishra, [3]*

Table 3. Conditions for *in-vitro* propagation

Explant	**Types of media**	**Further supplementation**	**Observations**	**Reference**
Shoot	Semisolid Murashige and Skoog (MS) growth medium	Sucrose (3% w/v), and different concentrations of growth hormones [6- benzylaminopurine or kinetin] + 1-naphthaleneacetic acid or Indole-3-acetic acid.	No growth of the explants observed when explants were cultured on the media without auxin or Cytokinin. Supplementation with different concentrations of growth hormones promoted multiplication of shoots.	[9]
Shoot	MS media	Sucrose (3% w/v), Agar (0.8% w/v) and [6 -benzyl aminopurine, 6- furfuryl aminopurine and thidiazuron]	MS medium supplemented with 2.22 µM BAP showed the maximum regeneration of shoots.	[10]

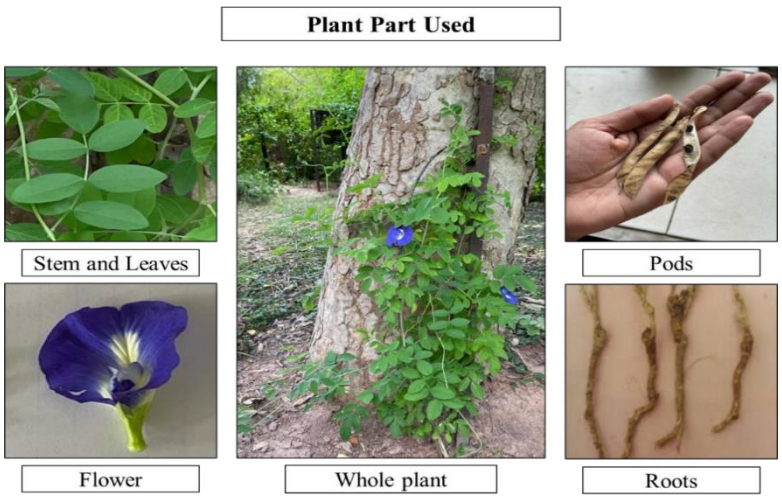


Fig. 1. Different parts of *C. ternatea*

In American, recently this plant cultivated in wet tropical climate, according to ecology this plant usually require direct sunlight, but occasionally partially shaded areas are preferable. For the germination, seeds are soaked in water overnight after these seeds will germinate within 1 or 2 weeks and flowering takes 4 to 5 weeks. The stem method is also used for the cultivation of *C. ternatea* [6].

This plant is drought sensitive, recent study in Malaysia was conducted for comparing the gemination rate in drought stress and normal conditions and the germination rate was reduced in drought stress encountered plant as compared to normal condition plants. The germination rate in drought stress and normal conditions was 42.5% and 56.25% respectively [7].

3.1 Micropropagation

Micropropagation of plant material is required to fulfill the demand of the natural product in the market. In-vitro culture techniques are the alternative technique to minimize the consequence of extinction of the plant [8]. Studies of *In vitro* propagation of the plant are summarized in Table 3.

4. PLANT DESCRIPTION

In different regions and systems of medicines, diverse parts of the plant are employed Fig. 1; [11].

4.1 Flowers

- It is the attractive part of the plant. These are available in single or paired form with various colors like mauve, white, dark and light blue.
- The pedicles and bracteoles can grow up to 4-9 mm and 12 m long respectively and its corolla consists of one standard petal, 2 keels and 2 wing petals. The standard petal is the largest one among all the petals [6] (Ashok and Geetha, 2012).
- Ashok and Geetha, 2012 suggest that typically the flower is bilateral, but the petal mutants are also present in nature that results in radial appearance of the flower. The colour variability of the flower is because of the presence of flavonoids which was reported by [12].

4.2 Leaves

- The leaves show pinnate venation with 7 leaflets [13].
- The terminal and base leaflets are bigger and smaller respectively.
- The dorsiventral structure is observed when the transverse section of the leaves is carried out.
- Calcium oxalate crystals are present along the veins prismatic. The palisade ratio and vein–islet number is 6.0 and 7.5 respectively (Jagbir Chahal et al*.,* 2010).
- Leaf blade have linear trichomes on both sides. The shape of the lamina is ovate, and its surface is smooth with hairy texture [14].

Organoleptic characters of *C. ternatea* flowers and leaves are presented in Table 4 [11].

4.3 Pods

The pods are flat, linear, olive, brown and black in colour, about 5-7 cm long containing 6-10 seeds in each pod [15].

4.4 Seeds

The seeds can be germinated by immersing them in water over night. After that, germination happens in 1-2 weeks, and blooming happens in 4 weeks. The plant needs full sunlight or partially shaded area to grow properly [6].

4.5 Stems

Stems are 3-5 meters long, hairy, bald, or occasionally upright. It is long, slender, and flexible in nature. It is light green to brownish in colour [16].

4.6 Roots

The root system of this plant is a strong taproot system [6]. Nodules of the root shows symbiotic association with nitrogen fixing bacteria, so it has capability to fix atmospheric nitrogen in them [15]. It has a brown colour with a bitter taste and characteristic odour [17].

5. TRADITIONAL USES

The plant is valued greatly for its varied therapeutic benefits in different traditional systems and folk medicine. Medicinal benefits of different parts of *C. ternatea* are presented in Table 5.

Table 4. Organoleptic characters of *C. ternatea* flowers and Leaves

Plant	Plant part	Picture	Organoleptic parameters	Observation
C. ternatea	**Flowers**	 **Fig. 2. *C. ternatea* Flowers**	Color Odour Shape Size Taste Season Inflorescence Sex	Indigo Odour less Funnel-shaped Length:1-1.5 in; Width: 2-3 cm Woodly Perennial Solitary Bisexual
	Leaves	 **Fig. 3. *C. ternatea* Leaves**	Color Odour Shape Size Taste Type Apex Base Margin	Green Characteristic Pinnate Length: 4-6 in; Width: 5-6 cm Bitter and acrid Compound Emarginate Symmetrical Entire

Table 5. *C. ternatea* traditional uses

Plant Part	Uses	References
Flower	• The paste of flower is used for the treatment of eye infection and headache. • Flowers are also used as an antidote for snakebites.	Alok et al. [18]
Leaves	• When a headache or swelling of a nearby gland occurs, juice from the leaves is combined with salt and placed around the ears to reduce discomfort. • Juice of leaves is used as an antidote against snakebite. • To treat swelling joints and used as poultices.	Alok et al., [18]
Seeds	• Used to treat colic, dropsy, swelling joints and enlargement of abdominal viscera. • It also possesses laxative, mild emetic and vermifugal properties. • Used as green manure and as an antidote for poisons.	Ashraf, *et al.,* [19]
Stem	• Used as antidote for snake bite and scorpion. • It acts as brain tonic because of the presence of some phytochemical, and it is also useful in urinary problems, throat, and eye related problems.	Sarma et al*., [*20]
Roots	• Ascetics, epilepsy, enlargement of the abdominal viscera, skin diseases, and sore throat. • Used as diuretic, laxative, mind tonic and purgative. • Serves to treat different ailments such as constipation, dyspepsia, eye conditions, eye conditions, enlarged abdominal organs, fever. • Rheumatism and ear problems are also treated using roots in the form of powder or decoction. • White variety flowered root juice is blown up the nose as a treatment for hemicrania.	[4,18,19]

Table 6. Nutritional composition of *C. ternatea*

Plant part	Nutrients value	References
Flowers	Iron = 0.14 mg/g Magnesium = 2.23 mg/g Potassium = 1.25 mg/g Protein = 0.32 % Sodium = 0.14 mg/g Zinc = 0.59 mg/g	Jeyaraj et al., [5]
Leaves	Fiber = 8.45 % Fat = 5.5 % Protein = 14.99 % Reducing sugar = 0.036 % Starch = 0.038 %	Swati et al., 2014
Seeds	Oil = 10 % Protein = 25 to 38 % Sugar = 5 %	[21]
Stem	Sugar = 112 ± 0.30 % Starch = 53 ± 0.47 % Protein = 39 ± 0.13 % Phenol = 37 ± 0.56 % Lipids = 18 ± 0.35 % (mg/gdw = milligram per gram dry weight)	
Roots	Sugar = 102 ± 0.59 % Starch = 42 ± 0.35 % Protein = 21 ± 0.49 % Phenol = 43 ± 0.13 % Lipids = 41 ± 0.14 % (mg/gdw = milligram per gram dry weight)	[22]

Table 7. Phytoconstituents reported from different parts of *C. ternatea*

Plant Part	Phytochemical constituents	References
Flower	Alkaloids, Carbohydrates, glycosides, phytosterols, saponins and tannins.	
Leaves	Alkaloids, flavonoids, glycosides, reducing sugar and Steroids	
Seeds	Alkaloids, amino acids, glycosides, mucilage, proteins, resins tannins	[20]
Stem	Carbohydrates, saponins, fixed oil, flavonoids, phenols	[16]
Roots	Flavonoids, resins, starch, tannins, taraxerone and taraxerol.	[18]

5.1 Other Uses

- It is locally called as Sangu Pushpam in Kancheepuram district of Tamil-Nadu, root powder with water is consumed to get relief from indigestion, eye diseases and headache.
- In Chhattisgarh, the fresh root bark (powder) acts as diuretic when administered with warm milk for 2 weeks and the seed act as purgative when administered with warm water once a day for the period of 3 days.
- In Irulas of the Kodiakkarai, *C. ternatea* flower paste is used to treat eye infection and headache.
- According to Dharampuram Taluk, Tamil-Nadu the seed powder of *C. ternatea* used for the treatment of constipation when mixed with pepper.
- According to Uttara Kannada district of Karnataka:

✓ The root juice is used to reduce fever when it is applied on the body.
✓ The root ash is involved in facial care.
✓ The burned seeds fume inhalation is useful to get relief from hiccups.

- ✓ The infusion of leaves are used for the treatment of eruptions (Jagbir Chahal et al*.,* 2010).
- ✓ In Malaysia, the color of the flower and leaves are used as colorant [19].
- ✓ In Philippines, different parts of the plant are consumed as vegetables [19].
- ✓ In Saudi Arabia, flowers of the plant are used as caffeine-free herbal tea [1].

6. NUTRITIONAL CONTENT

There are various amounts of nutrients present in plants. Some of the nutrients of *C. ternatea* present in different parts of the plant are mentioned in Table 6.

7. PHYTOCONSTITUENTS

The plant is rich in primary and secondary metabolites. Different parts contain varied phytoconstituents presented in Table 7.

7.1 Anthocyanins

The biologically and commercially important constituents includes anthocyanins, cyclotides, flavonoids, steroids etc. Cyclotides are the stable peptides which are present in the whole plant. Butelase 1 is a cyclotide processing enzyme with having capability of ligating various range sizes (26 to >200 residues) of peptides which further used as cyclotide containing pesticide [13]. Anthocyanins, which are flavonoid chemicals give plants various colour, from mild pink to deep blue and purple [23]. Because of the intense blue colour of the petals, it has been determined that the primary phytochemicals in the *C. ternatea* flower is anthocyanins.

The evaluation of anthocyanin content: Amount of anthocyanin present in *C. ternatea* can be evaluated by formula:

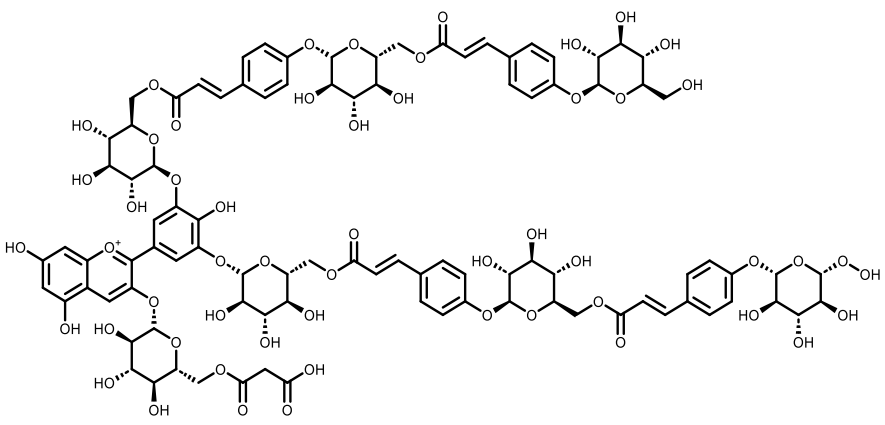
$$\gamma = (A.M.F) / (m. \varepsilon .l)$$

where γ = Anthocyanin mass concentration.
A = Absorbance.
M = Anthocyanin's molar mass, 500.8 gmol-1
F = Dilution ratio of C. ternatea flower.
V = Extraction solution volume.
m = Mass of *C. ternatea*, ε is attenuation coefficient, 27300^{-l} mol^{-1} cm^{-1} and the width of cuvette, 1 cm [24].

The anthocyanins extracted from this plant, are ternatins A1-A3, B1-B4, C1-C4, and D1-D3. These are blue acylated anthocyanins that are derived from delphinidin. Ternatins structure is identified as malonylated delphinidin 3,3′,5′-triglucosides, having 3′,5′-side chains with have ability alternate D-glucose and p-coumaric acid units because they are highly acylated with p-coumaric acid [25,4] (Klara et al*.,* 2023). All ternatins produced 6-malonyl-glucose while hydrogen peroxide oxidation which indicates that malonic acid is attached to 3-glucoside of each ternatin. Anthocyanins are extracted by polar solvent because they have the affinity to extract them. Lower pH was found to the optimal for the extraction of anthocyanins [26,27]. Depending on the pH, anthocyanin's colour changes from acid to base. The blue colour anthocyanins appear in the pH range of 5–7 by the quinonoid base form which can be easily degraded. The stableness of ternatins can be improved by high degree of acylation and glycosylation [28].

The stability of anthocyanins will be calculated by using formula:

Absorbance decay percent (%) = $[(A_0 - A_t)/A_0] \times 100\%$



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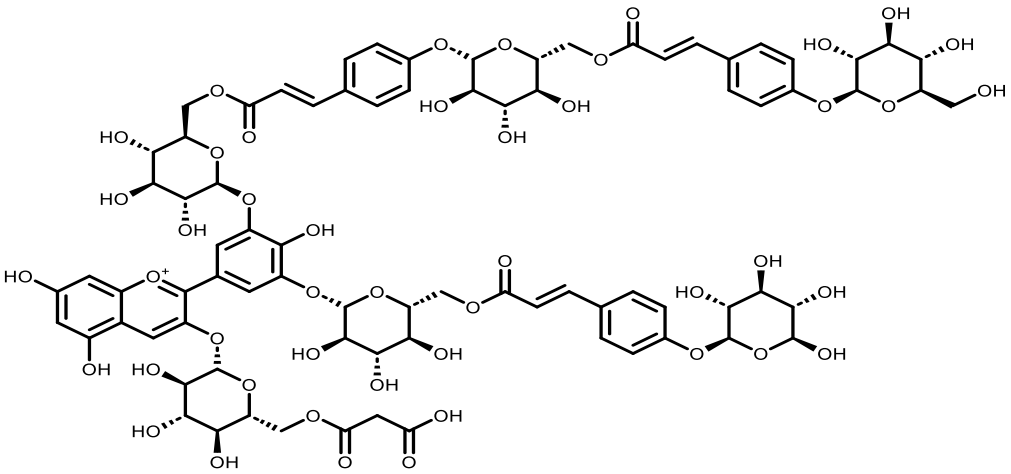

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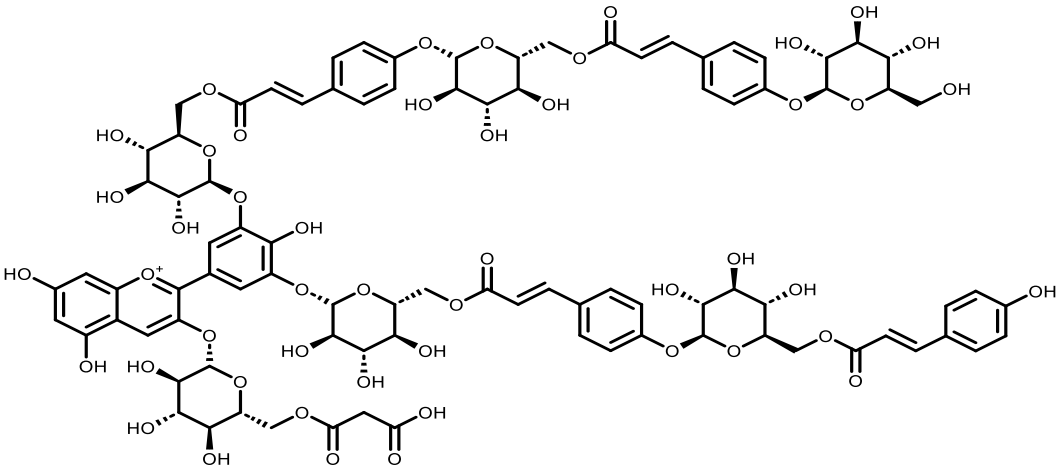

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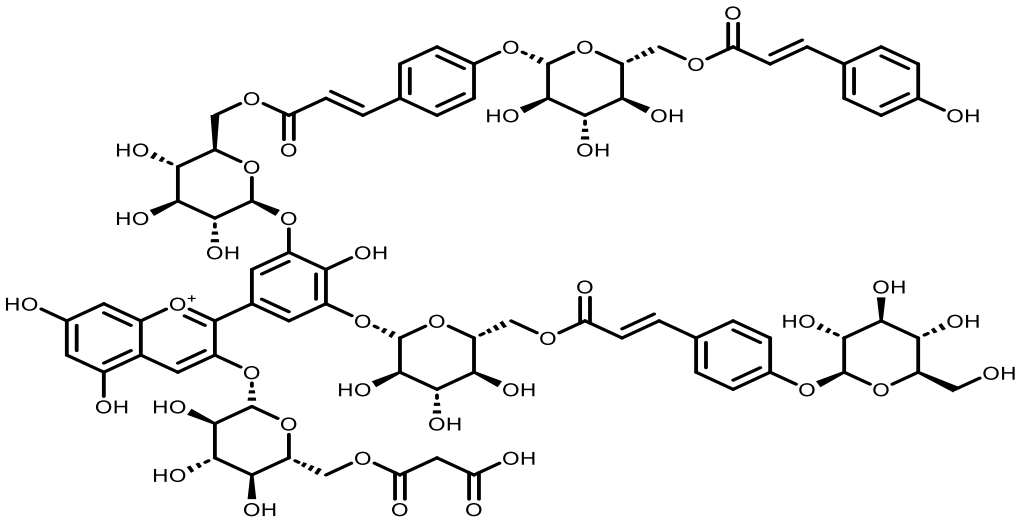

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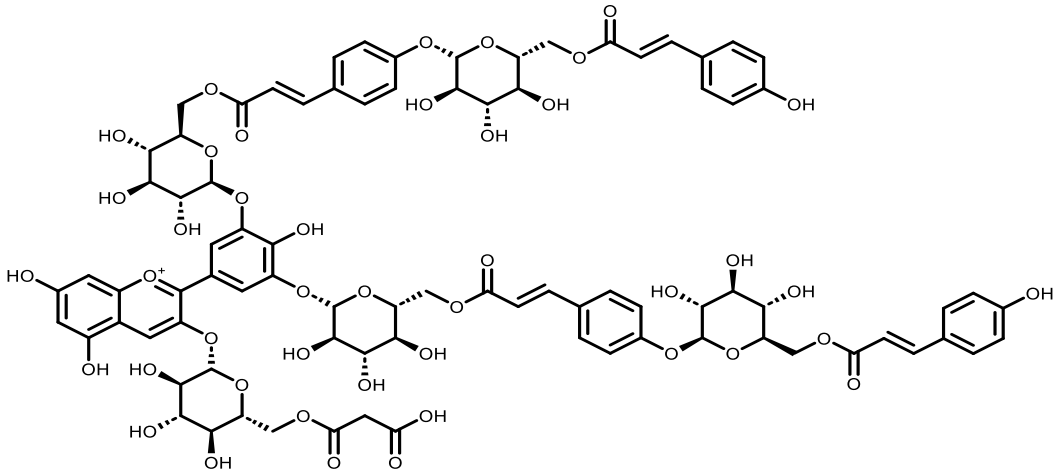

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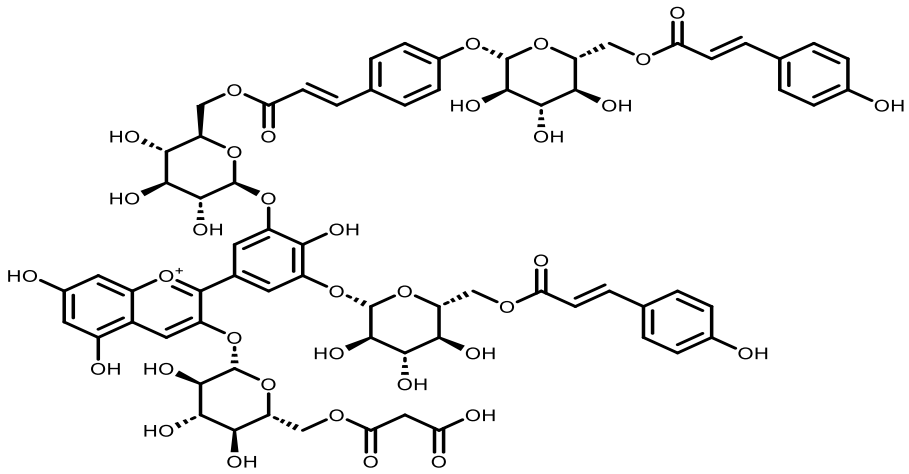

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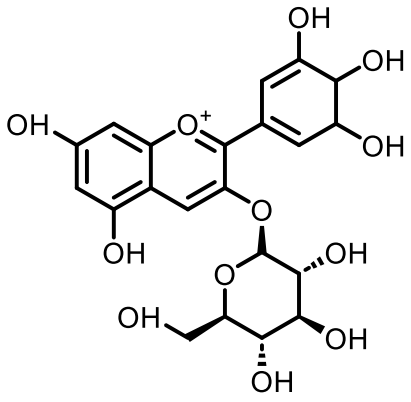


(g)

Fig. 4. Anthocyanins present in *C. ternatea:* (a) Ternatin A1, (b) Ternatin A2, (c) Ternatin B1, (d) Ternatin B2, (e) Ternatin D1, (f) Ternatin D2, (g) Delphinidin-3-O-glucoside

7.2 Flavonol Glycosides

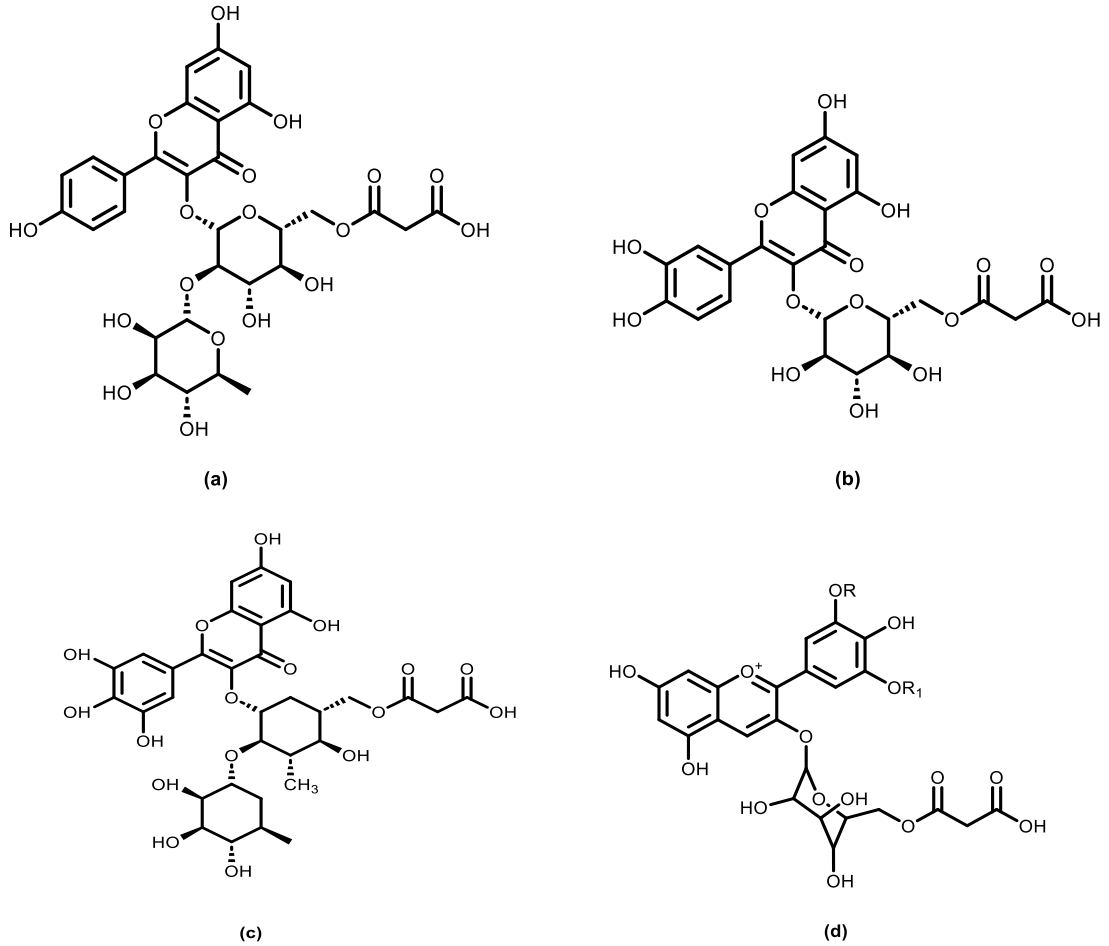
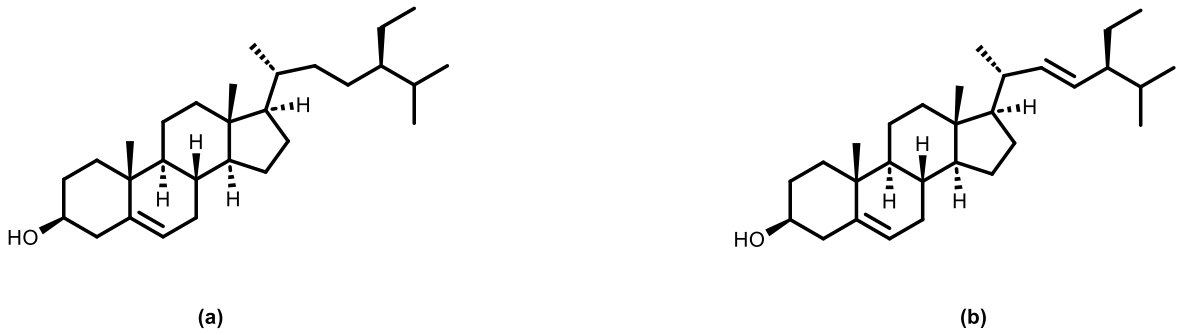


Fig. 5. Major flavonol glycosides are present in *C. ternatea:* (a) Kaempferol; (b) Quercetin; (c) Myricetin; and (d) Delphinidin-3-malonyl glucoside

7.3 Phytosterols

Phytosterols are present in the plant [6] are presented in Fig. 6.



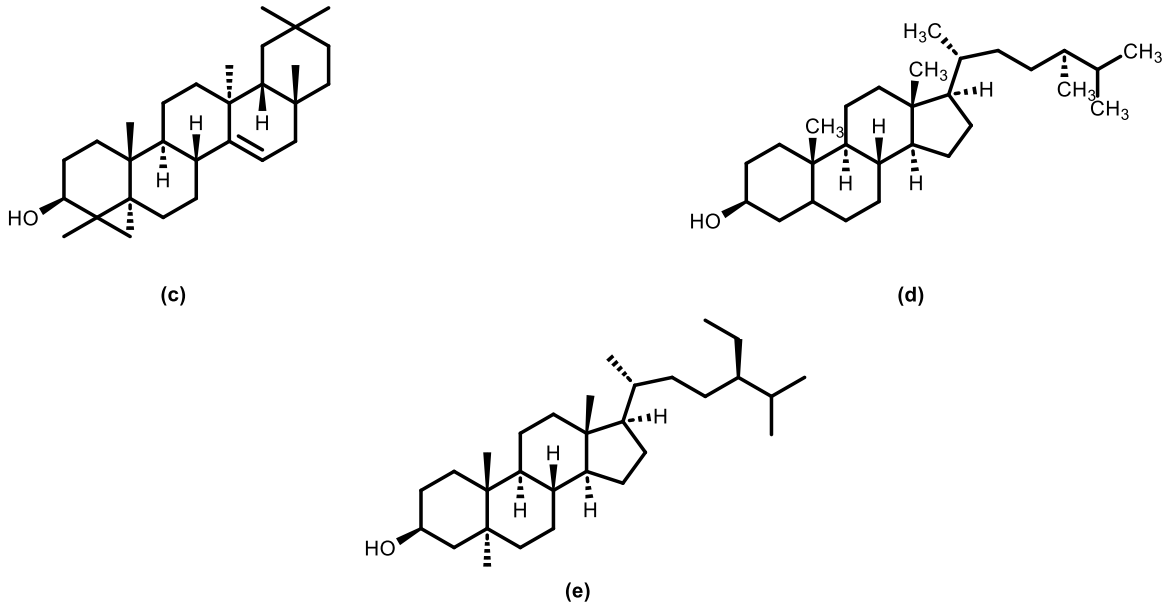


Fig. 6. Phytosterols in C. ternatea (a) β-sitosterol; (b) stigmasterol; (c) taxaxerol; (d) campesterol; (e) sitostanol

8. EXTRACTION METHODS

Extraction is the essential step for the isolation of valuable phytochemical from the plant material. There are various methods available for the extraction of phytochemicals and these methods are selected based on the nature of the plant material [29]. Extraction methods are classified into two types: conventional methods (traditional methods) and non-conventional methods (modern methods) [5]. There are various factors which affect the yield of extraction like pH, solvent (polar or non-polar), temperature etc. [30].

Various methods have been employed to extract phytoconstituents from this plant (Table 8).

Among all the methods extraction assisted with ultrasound (modern method) have proven to be more effective method for anthocyanins extraction.

9. PHARMACOLOGICAL ACTIVITIES

Numerous pharmacological studies (*in-vitro* and *in-vivo* investigations) have been carried using various extracts of the plant. Table 9 sums up the findings of investigations in the last 10 years.

Table 8. Extraction of different compounds from *C. ternatea* by different extraction methods and solvents

Extraction method	Solvent	Compound/phytochemical	Yield	Reference
Maceration	Water	Dye strain	45.52 %	[31]
Cold water extraction	Water	Phenols	185.3 mg/g	[32]
Hot water extraction	Water	Phenols Flavonoids	239.5 mg/g 128.3 mg/g	
Ultrasound assisted extraction	Distilled water	Anthocyanins	-	[33]
Maceration	Hydro alcohol	Flavonoids	246.6 %	
Microwave assisted extraction (decoction)	Distilled water	Dye strain	48.61 %	[34]

Table 9. Various pharmacological activities of *C. ternatea*

Antioxidant activity:

Plant (Part used)	Extract	Dose	Model	Result/ Observations	Reference
White and Blue (roots)	Petroleum ether, Chloroform and Methanol extract	50-600 µg/ml	DPPH assay	Methanol extract of white variety roots show most significant antioxidant activity.	[35,36]
White and Blue (leaves)	Petroleum ether, Chloroform and Methanol extract	50-600 µg/ml	Hydroxyl Radical Scavenging Activity	Methanol extract (white flower) leaves show most marked activity.	
White and Blue (leaves)	Petroleum ether, Chloroform and Methanol extract	50-600 µg/ml.	DPPH assay	Methanol extract of white variety show most significant activity.	[37]
White and Blue (Flowers)	Flower petal extract	400 µg/ml	Oxygen Radical Absorbance Capacity method and DPPH assay	The results of the study showed that petal extract prevent morphological alteration of erythrocytes.	
Flowers	Anthocyanin extract	pH 5-7	DPPH assay	Strong antioxidant effect in the pH range 4–7 and a sharp decrease when the pH exceeded 7.	[28]
Flowers	Aqueous extract	100 mg/kg	DPPH assay and Bisphenol A (BPA)-induced oxidative injury in female murine reproductive system.	Protective effects in female murine reproductive system with regards to improve the percentage of pregnancy and litter size and potent antioxidant activity.	[38]
Flowers	Ethanol extract lotion	0.05%, 0.1% and 0.5%	DPPH assay	0.1% lotion showed potent antioxidant activity with IC_{50} 37.92 ppm.	[39]
Flowers	Ethanol extract	Different concentration	ABTS, DPPH assay	Ethanol extract exhibits potent antioxidant activity in ABTS and DPPH assay with IC_{50} 10.23 ± 0.186; 2.77 ± 0.020, respectively.	[40]

Plant (Part used)	Extract	Dose	Model	Result/ Observations	Reference
Flowers	Aqueous extract	Different concentration	ABTS, DPPH, FRAP and Hydrogen Peroxide (H_2O_2) Scavenging Assay	Strong antioxidant activity in ABTS, DPPH and Hydrogen Peroxide (H_2O_2) Scavenging Assay with (IC_{50}: 2.51%, 17.07%, 5.56% and 26.62%) respectively.	[41]
Flowers	Fresh, dried flower and *C. ternatea* flowers + citrus species	Different concentrations	DPPH, Hydrogen Peroxide (H_2O_2) Scavenging Assay	Dried flower showed potent antioxidant activity.	

Antidiabetic activity:

Plant (Part used)	Extract	Dose	Model	Result/ Observations	Reference
Leaves	Methanol, Water, Petroleum ether and Chloroform extracts	200 -400 mg/kg	Streptozotocin Induced Diabetic Rats.	Methanol extract (200 mg/kg) decreased blood glucose level.	[35]
Roots	Alcohol extract	100 mg/kg	Juvenile diabetic rat experimental models.	Alcohol extract prevented the issues which were related to brain hippocampal CA3 area and pancreatic tissue.	[42]
Leaves	Ethanol extract	400 mg/kg	Streptozotocin induced model	Decrease in the blood glucose, creatinine, glycosylated hemoglobin, insulin, liver marker enzymes, and urea levels.	[43]
Flowers	Hydro-ethanol extract	400 and 800 mg/kg	Diabetes mellitus and dyslipidemia in rats	Pancreatic CAT, Superoxide Dismutase (SOD) and protein levels were increased. Pancreatic Malondialdehyde (MDA), IL-18 levels, glycogen gene expression of pancreas and IL-6 protein expression of pancreas in DM and dyslipidemia rats were reduced.	[44]

Nootropic potential:

Plant (Part used)	Extract	Dose	Model	Result/ Observations	Reference
Leaves	Ethanol extract	200 and 400 mg/kg	Y-maze; Morris water maze; Radial arm maze	Reduction in cholinesterase activity, reduction in nitric oxide as well as lipid peroxide level and enhances the levels of catalase, superoxide dismutase and glutathione levels.	[45]
Roots	-	200 mg/kg and 300 mg/kg	Cerebral hypoperfusion induced memory deficits in a rat model	Inhibition of acetylcholinesterase activity in the frontal cortex and hippocampus of the rat brain.	[46]
	Alcohol extract	50 and 100 mg/kg	Scopolamine induced amnesia model.	AChE activity was significantly decreased leading to increase in the level of ACh content .	[37]
	Aqueous and Hydroalcoholic extracts	100, 300, and 500 mg/kg	100, 300, and 500 mg/kg	Hydroalcoholic extract provides protection against STZ-induced cognitive impairment by reducing oxidative stress, cholinesterase activity, and ROCK II expression.	
Aerial and Root parts	Ethanol extract	300 and 500 mg/kg	Electroshock-induced amnesia in rats.	Significant memory retention was produced, and the root extract was more effective.	[6]

Anti-inflammatory and Antipyretic effects:

Plant (Part used)	Extract	Dose	Model	Result/ Observations	Reference
Leaves	Water, ethanol, and petroleum ether	100-400 mg/kg	Carrageenan Induced paw oedema	Ethanol extract decreased inflammation.	Bhatia et al., 2014
Blue flowered (roots)	Methanol extract	200, 300 and 400 mg/kg	Pyretic potential on normal body temperature and Yeast-induced	Substantial reduction in normal body temperature and yeast- provoked elevated temperature.	[35]

Plant (Part used)	Extract	Dose	Model	Result/ Observations	Reference
			pyrexia in albino rats		
Flowers	Ethanol extract	400 mg/kg	Carrageenan-induced paw oedema in rats	Attenuation of inflammation.	[47]
Roots	Methanol extract	200-400 mg/kg	Carrageenan-Induced paw oedema in rats	Marked anti-oedematous activity.	[48]
Roots	Methanol extract	200, 300, and 400 mg/kg	Yeast-induced pyrexia	Marked decline in normal body temperature.	[49]

Antibacterial and Antihistaminic activity:

Plant (Part used)	Extract	Dose	Model	Result/ Observations	Reference
Roots	Ethanol extract	100, 125 and 150 mg/kg	Antihistaminic activity using Clonidine and haloperidol induced catalepsy in mice.	Significant inhibition of clonidine induced catalepsy.	[35]
Flowers	Ethyl acetate and Dichloromethane fraction	Various concentrations	Antibacterial activity against *Staphylococcus aureus* and *Escherichia coli.*	Potent antibacterial activity exhibited by both with a Minimum Inhibitory Concentration (MIC) value of 0.156 mg/ml.	[50]

Anticonvulsant activity and Analgesic activity:

Plant (Part used)	Extract	Dose	Model	Result/ Observations	Reference
Leaves	Water, ethanol and petroleum ether	100-400 mg/kg	Tail flick method	Ethanol extract exhibits significant analgesic activity.	Bhatia et al., 2014
Aerial parts	Methanol extract	100 mg/kg	Pentylenetetrazol and Maximal electroshock induced seizures.	Postponed the onset of convulsions and reduction of the duration of tonic hind limb extensions.	[42]
		230 and 460 mg/kg		Did not show effective results against PTZ and MES induced seizures in rats.	

Antidepressant, anti-anxiety activity:

Plant (Part used)	Extract	Dose	Model	Result/ Observations	Reference
Roots	Methanol extract	100 and 400 mg/kg	Elevated plus maze and light/dark exploration test.	Time spent in the open arms of EPM increased and there was increase in time spent in the light box at higher doses of CT in light/dark exploration test.	[37]
Roots	Methanol extract	100 and 400 mg/kg	Tail suspension test in mice	Noteworthy decrease in the duration of immobility.	[51]

Hepatoprotective activity:

Plant (Part used)	Extract	Dose	Model	Result/ Observations	Reference
White and Blue Flower (Leaves)	Alcohol extract	200 mg/kg	Paracetamol induced liver toxicity.	Protection against paracetamol-induced liver toxicity and acts by reducing the increased levels of aminotransferase, and bilirubin as well as histopathological damages caused by the liver toxicity.	[42]
		200 mg/kg	Carbon tetrachloride induced liver toxicity.	White-Flowered leaves extract showed more better hepato-protective activity as compared to the blue-flowered leaves extract.	

10. SAFETY AND TOXICITY STUDIES

Toxicity studies are evaluated by using methods to determine the safe dose of product to ensure the safety of human being. The toxicity of the natural compounds will depend on the availability of the chemical constituents present in them. Medicinal plants commonly have beneficial effect but some of the naturally occurring compounds show toxic effect [52]. *C. ternatea* extracts have been examined and are reported to be safe.

- Ethanol extract of roots has LD_{50} >1300 mg/kg in mice with no deaths observed up to 3000 mg/kg in mice in acute oral toxicity studies. There was no mortality or disorder observed up to 72 hours after the administration of single dose of 1000 mg/kg in rats.
- Ethanol extract of aerial parts of *C. ternatea* was safe up to 2 g/kg (p.o.) in rats. Animals involved in the study exhibit reduced mobility but no sign of convulsions [53].

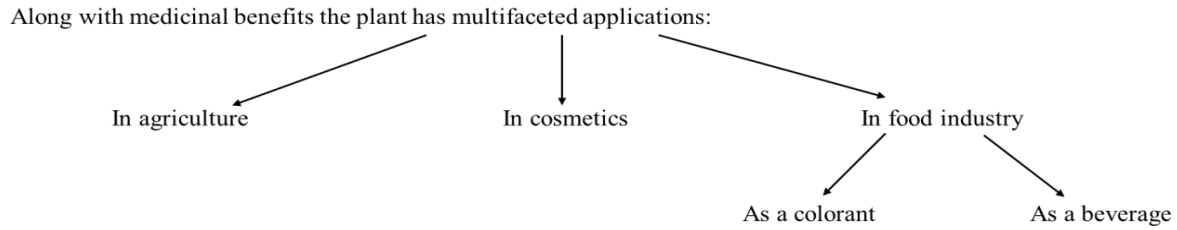
11. CLINICAL TRIALS

Clinical trials are carried out to make drug development more efficient and informative for the population. The clinical data will help to find out the suitable range of dose for human being. Some of the clinical trials of *C. ternatea* were reported which are presented in Table 10.

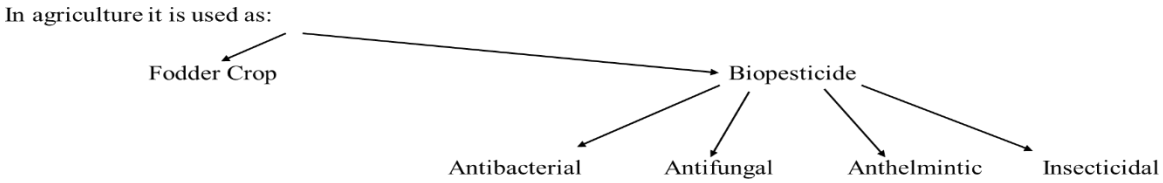
Table 10. Clinical trials of *C. ternatea*.

Plant (Part used)	Extract/ Formulation	Dose/ Route	Participant	Result/ Observations	Reference
Flowers	Aqueous	1-2 g in 400 ml water (orally)	Healthy Adult Males	Antioxidant capacity of plasma increased. postprandial sucrose and insulin levels were decreased. Postprandial antioxidant status was enhanced.	Chusak et al., 2018b
Leaves	Lepa (Ayurvedic formulation)	-	Either gender	Formulation was effective for skin diseases (Dadru).	[54]

12. APPLICATIONS



12.1 Agriculture



12.1.1 Cultivation of *C. ternatea* as a fodder crop

It is palatable hay for cattle and its yield reaches approximately 17-29 tons/hectare. The quantity of dry matter content and digestibility of the plant depends on the timing of harvesting. It increases the energy density of the feed as well as possess high amount of nitrogen because of the presence of low acid detergent fibre content. It also served as source of carotenoids [13].

12.1.2 Biopesticide activity

12.1.2.1 Antibacterial and antifungal

Finotin protein also possesses antibacterial activity against *Xanthomonas axonopodis*. Ethanol extract of the plant exhibits antibacterial activity against different *Bacillus* species, *Enterococcus faecalis*, *Staphylococcus* species, *Streptococcus* species, and [55].

Ultrasound assisted extraction of the plant shows greater amount of antibacterial property due to high anthocyanin content (Anthika et al., 2015).

Methanol leave extract of the plant shows antifungal activity against mold fungus *Aspergillus niger* [56].

12.1.2.2 Anthelmintic

Numerous investigations revealed varying levels of resistance against the parasitic root-knot nematode (*Meloidogyne incognita*) were shown by 27 homozygous lines of *C. ternatea.* Its methanolic extract exhibit 93% inhibition towards *M. incognita* [13].

12.1.2.3 Insecticide

[Kelemu et al*., [*57]; Poth et al*., [*58] reported that *C. ternatea* act as insecticide due to the presence of proteins and peptides. It contains a protein named finotin which cause 100% larval mortality in concentration 1% w/w and 5% w/w to bruchids *Acanthoscelides obtectus* and *Zabrotes subfasciatus*, respectively.

Larval growth retardation is also reported in dose dependent manner lepidopteran species (*Helicoverpa armigera*), when cyclotide (Cter M) was added in the diet [58].

The extracts of *C. ternatea* served as environmental-friendly natural insecticide [59].

12.2 Cosmetics

The flowers are rich in antioxidant constituents which are valuable to combat oxidative stress and delay skin ageing. According to Dziok et al*.,* 2021 due to the antiaging property of *C. ternatea* it is highly demanded in the market as pharmaceutical and cosmetic product because it helps in improving the youth appearance and keep skin hydrated. Different formulations of *C. ternatea* are presented in Table 11.

Table 11. Different cosmetic formulations of *C. ternatea*

Plant part	Formulation	Composition	Benefits	Reference
Whole plant	Face wash gel	*C. ternatea* alcoholic extract Water Propylene glycol Sodium lauryl sulphate Triethanolamine	Provides clear glossy and healthy skin.	[60]
Seeds	Sunscreen	*Cucurbita reticulata* extract *Cucurbita moschata* extract *C. ternatea* extract *Aloe vera* Sun products	*C. ternatea* showed higher sun protective activity than sunscreen product.	Mustaffa et al*.,* 2018
Flower	Sun block lotion	*C. ternatea* extract *Pandanumusa Paradisiaca* extract Virgin coconut oil Glycerin Stearic acid Triethanolamine Methylparaben	Provide protection against the UV rays.	[61]
Flower	Lotion (0.05%, 0.1% and 0.5%)	*C. ternatea* extract Stearic acid Triethanolamine Liquid Paraffin Cetyl alcohol Glycerin Methyl paraben Propylparaben Aquadest	0.1% concentration of telang flower extract has a very strong antioxidant activity because it has an IC_{50} value 37.92 ppm.	[39]
Flower	Eye shadow	*C. ternatea* extract *Caesalpinia sappan* extract Cetyl Alcohol Stearic Acid Petrolatum Polawax Polysorbate 80 Sorbitan Monooleate 80 Mineral Oil Butylate Hydroxy Toluene Triethanolamine Propylene Glycol Methyl Paraben Propyl Paraben Water Talcum	This combination of eye shadow showed mild irritation but when combined with some other natural dye provide more stable formulation.	[62]

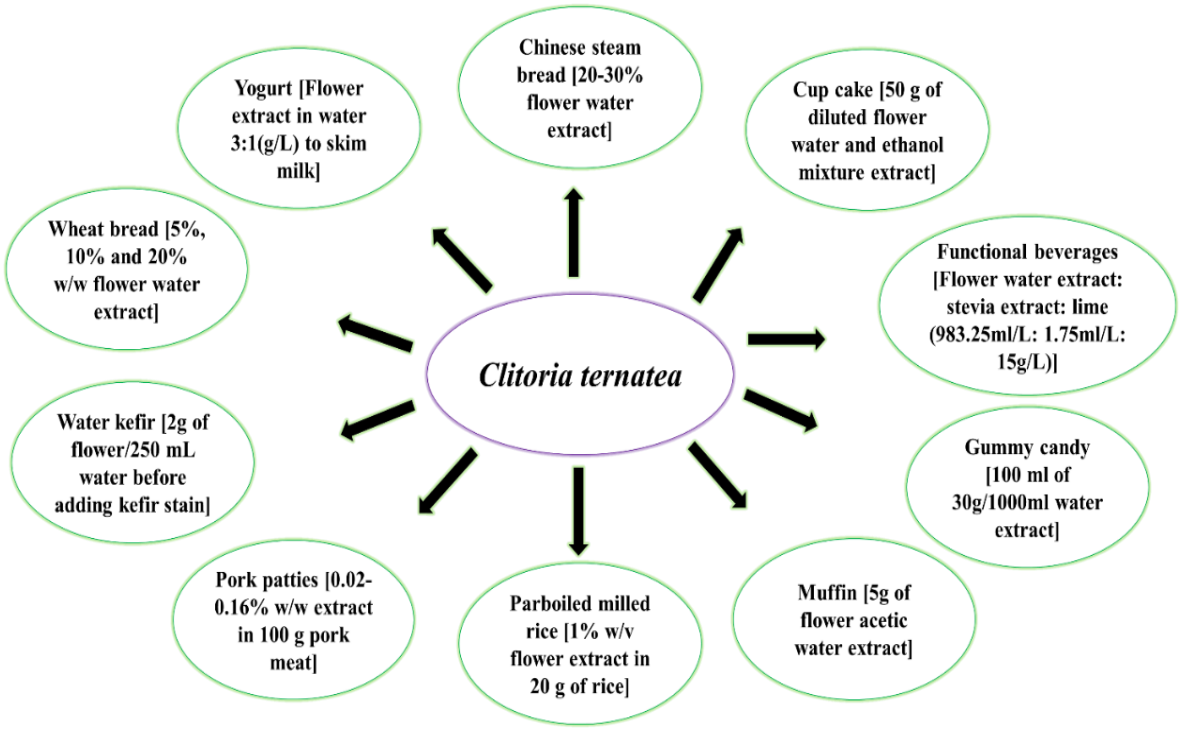


Fig. 7. *C. ternatea* in food products application

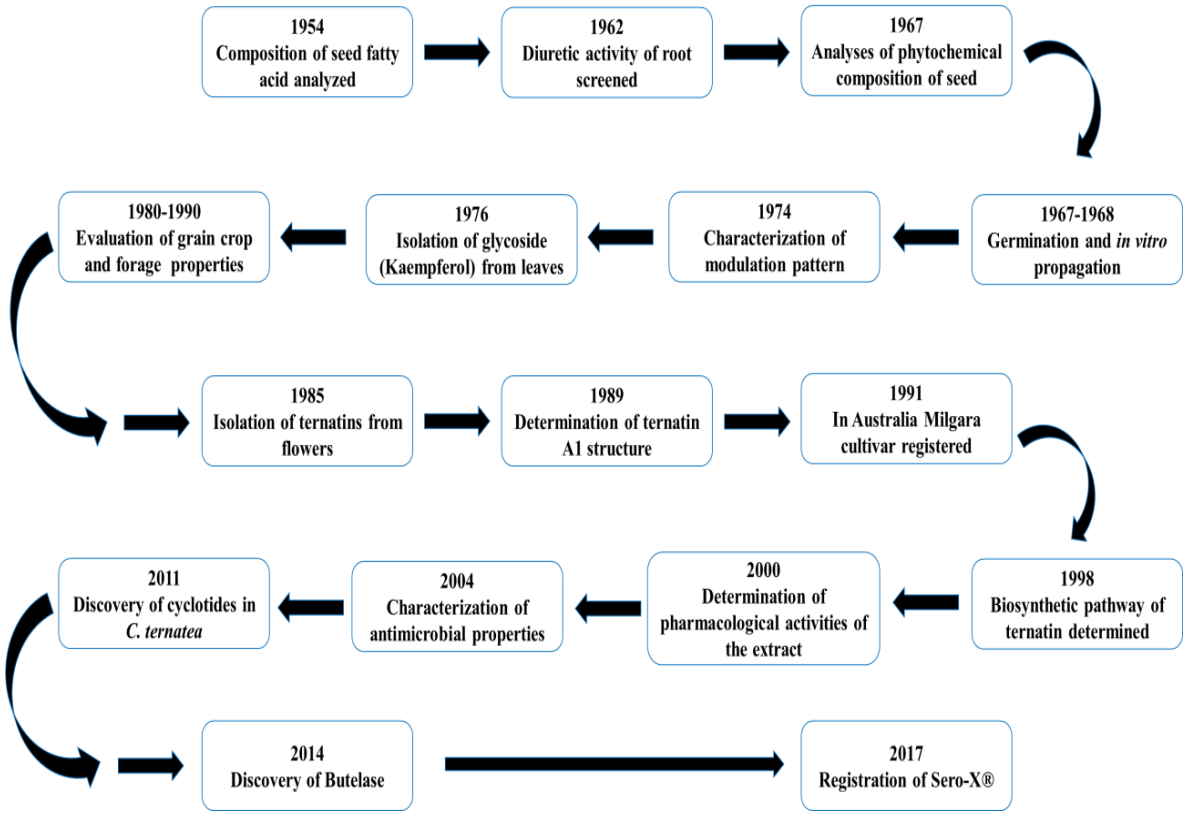


Fig. 8. Milestones of *C. ternatea* Studies (1954 to 2017)

12.3 Food Product

Some of the studies reported that if the anthocyanins present in *C. ternatea* flowers were used as food colorant they possess potent antioxidant activity. Leong et al,[63] reported that anthocyanins can play two roles: one is coloring agent, and the other one is bio preservative. Application of *C. ternatea* in different food products are presented in Fig. 7 [64-68].

Fig. 8 highlights the milestones in the systematic study of this plant.

13. CHALLENGES AND FUTURE DIRECTION

To get the regular supply of the plant better Good Agricultural Practices (GAP) to be documented. A limitations of *C. ternatea* plant is that the colour pigments of the plant are unstable in nature and readily degrade when expose to different environmental conditions like light, pH, and temperature (Kaushik et al*.,* 2022). To prepare stable formulations of the plant pigments, new drug delivery systems may be investigated. Microencapsulation or nanoparticle formulations may be a suitable way to safeguard the natural plant pigments. In order to develop the plant/ plant product further evidence should be strengthened with detailed pharmacological as well as human trials. Comprehensive investigations will ultimately lead to the development of a medicine/ nutraceutical or cosmeceutical from this delicate but powerful plan [69,70].

14. CONCLUSION

The present review highlights the versatile role of this beautiful plant. *C. ternatea* is not only an ornamental plant but also offers diverse benefits in the medicine fields, cosmetics, food industry and agrotechnology. *C. ternatea* is an abundant source of different phytoconstituents which offer health benefits to humans. It acts as an additive when supplemented with functional food, pharmaceutical drug, and results in an increase in treatment efficiency. The plant demonstrates a variety of actions, and it exhibits a low toxicity profile. From the above-mentioned data, we conclude that *C. ternatea* is versatile, safe, and effective.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

CONSENT AND ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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