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Pharmacological, Phytochemical and Medicinal Use of *Tecomela Undulate*: A Threatened Species of Rajasthan

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ABSTRACT

Tecomella undulata (Rohida), a deciduous tree belongs to family Bignoniaceae. It is indigenous to the arid and semi-arid region of India, particularly thriving in Rajasthan's extreme climatic condition ranging -2 °C up to 48 °C. The plant is currently recognized as a threatened species in Rajasthan, due to overharvesting and its important ecological role. In traditional Ayurveda and tribal medicine, T. undulata has held significant esteem. Historically, its bark and other parts have been employed in addressing a broad spectrum of health issues including syphilis, leucorrhoea, leucoderma (vitiligo), enlarged spleen, traumatic wounds, hepatic disorders, anorexia, flatulence, tumors, worm infestations, and piles.Extracts from the bark and leaves contain radermachol, lapachol, tecomaquinone I, α- and β-lapachone, and the sterols such as stigmasterol, β-sitosterol, alongside triterpenoids oleanolic acid, ursolic acid and betulinic acid. Betulinic acid and ursolic acid are recognized for their strong anti-HIV effects, while triacontanol, present in the leaves, serves as a plant growth regulator. Pharmacological studies in rodents and in vitro models have validated several therapeutic properties. Ethanol leaf extract demonstrates anti-ulcer, anti-inflammatory, and laxative effects in rodent models, reducing ulcer severity, decreasing inflammation and promoting bowel movements. Methanolic bark extracts and butanol fractions have shown anticoagulant and antioxidant activities in vitro, significantly extending clotting time and scavenging free radicals.GC-MS profiling of leaf and bark extracts has also detected flavonoids such as quercetin and kaempferol in addition to sterols like sitosterol and stigma sterol. These compound classes contribute to the plant's antimicrobial, anti-inflammatory and antioxidant effects. Overall, Tecomella undulata emerges as a species with a diverse pharmacological profile demonstrating anti-inflammatory, anti-ulcer, laxative, antidiabetic, antiviral, antimicrobial, antioxidant and anticoagulant effects. Given its threatened status and cultural significance, further systematic phytochemical research and conservation efforts are highly recommended to isolate bioactive constituents and explore therapeutic potential while supporting species preservation.

***Keywords**: Bioactive Compounds, Photochemical, Pharmacological, Tecomela Undulate, Threatened Species.*

Introduction

A small tree found in arid regions of India, Pakistan, and Arabia, Tecomella undulata (Sm.) Seem. (family Bignoniaceae) (Table 1) is significant both economically and pharmaceutically. Known by many as "Desert teak" or "Marwar teak," it is the primary timber source among the tree species found in Rajasthan, India's desert region (Ranawat and Kumari, 2022). According to Avalos and Howar (2000), the Bignoniaceae is a large family of flowering trees and shrubs that includes 120 genera and almost 800

species in tropical and subtropical regions. According to Table 2, the plant is also known by a number of colloquial names (Kumawat et al. 2012). Due to its growing demand in the lumber and pharmaceutical industries, as well as insufficient conservation efforts, this widely used agroforestry tree of arid regions is in danger of going extinct. Rajasthan, India, has now classified this species as "threatened" (Kalia et al. 2014).

One of the main issues and a hindrance to the successful establishment and growth of this tree is its susceptibility to an excessive number of diseases and pests. Traditionally, seeds are used to propagate it; however, because of airborne seed dispersal to distant locations, harsh environmental conditions during seed dispersal, improper seed harvest and storage, and short seed viability, natural plant regeneration is poor. The tree grows very slowly, and there are no effective vegetative propagation techniques for its quick growth. As an alternative, efforts have been made to propagate this tree in vitro (Singh et al. 2020, Kaur et al. 2019); however, this method has numerous drawbacks, such as slow growth, low rooting rates, issues with culture establishment, and low field establishment rates.

Furthermore, morphological and molecular markers provide limited information about genetic diversity in this species (Kalia et al. 2014). Breeding programs to improve T. undulate have not yet been started. There is some literature on T. undulate's cytology, function in silviculture and agroforestry, relationship to vesicular arbuscular mycorrhiza, and use of biotechnological tools (Kalia et al. 2014).

In both the folk and traditional branches of indigenous medicine, *T. undulata* has a well-established reputation for having beneficial therapeutic qualities. Numerous medicinal properties of plants are well known, including hepatoprotective, antibacterial, antimicrobial, antifungal, anti-termite, immunomodulatory, anticancer, cytotoxic, analgesic, anti-inflammatory, and anti-obesity properties (Jain et al. 2012; Rohilla and Garg 2013). The traditional compound used to treat liver and spleen disorders, oedema, and anaemia is Rohitakarishta, an ayurvedic medication derived from T. undulata (Kalia et al. 2014). However, there has been a recent exponential rise in research publications on the identification of bioactive constituents and the confirmation of pharmacological effects. Current research also summarises the latest data on Tecomellaundulata's pharmacological and phytochemical properties.

Taxonomic Characteristics

Tecomella is a large shrub or small tree that can grow to a height of 2.5 to 5 meters. Its drooping branches are glabrous and, when young, have tiny stellate hairs. The simple, typically sub-opposite, greyish-green leaves measure 5–12.5 cm in length and 1–3.2 cm in width. They have a narrowly oblong apex, obtuse, emarginated margins, and an entire, somewhat undulating, slightly cuneate base. The midrib is prominent below, and the petioles are 1-2 cm long, terete, and glabrous. Few flowered corymbose racemes with short lateral branches end in large, lovely, odourless flowers that are yellow, orange, or red in colour. The calyx is 8–9 mm long, campanulate, green or yellow, and the lobes are 3 mm long, broadly ovate, obtuse, mucronate, frequently recurved, and have a few black dots on the outside. The pedicles are 1-2 cm long, terete, minutely stellately hairy, and persistent pedicel bases.

Corolla Five sub-equal rounded lobes, 5–7 cm long, yellow or yellow orange, campanulate, veined. Glabrous filaments, stalens exerted, anterior 30–35 mm long, posterior 2.5 mm long. The ovary is on a yellow annular disc, the style is up to 4 cm long and glabrous, and the stigma is bi-lamellate, elliptic, 3.5 mm long, with spathulate-oblong, rounded lobes. The tree blooms in April and May and then bears fruit. The fruit is a smooth, curved, linear-oblong capsule that measures 15–35 cm by 9–10 mm. It has thin eds and wings that are narrow and thin at the apex of the seed (Pandey 1970; Bhandari 1978; Chal et al. 2011). The wood is close-grained, mouldy, grey or yellowish brown with light streaks, and it is durable, tough, and strong.

Table 1: Classification of Plant

Kingdom	Plantae
Order	Lamiales
Family	Bignoniaceae
Genus	*Tecomella*
Species	*T. Undulata*

Table 2: Vernacular name of *Tecomella undulata*

S. No.	Locality	Popular/Common name
1.	Baluchistan	Rori
2.	Bolan	Parpuk
3.	Bombay	Lohera, Lohuri, Rakhtreora, Rugtrora, Roira
4.	Hindi	Rugtrora
5.	Lasbala	Lahira
6.	Marathi	Rakhtroda,Raktarohida,
7.	Marara	Rohira, Roira
8.	Punjab	Lahura,Luar, Rohira, Roir
9.	Pushtu	Raidawan, Rebdan, Rebdun
10.	Sanskrit	Chalachhada, Kushalmali, Kutashalmali
11.	Sind	Khen, Lahero, Lohuri

Source: kumawat et al., 2012

Medicinal Uses

Both historically and in light of more recent scientific discoveries, the plant's therapeutic properties have been investigated. Bark powder is particularly recommended in cases of ascites with hepatosplenomegaly. Because it is an excellent blood purifier, it is good for hepatitis. Many herbal treatments for inflammatory liver diseases, including Livo-plus, Liv-52, Herboliv, Amylcure, Livosan, and Exol, contain bark as a main ingredient. Furthermore, it possesses potent antibacterial (Parekh et al., 2005), cytotoxic (Krishnarajua et al., 2005), immunomodulatory (Choudhary, 2011), analgesic (Ahmad et al., 1994), and anticancer (Ravi et al., 2011) qualities. It is also used to treat eczema (Shah et al., 2006).

The bark of the plant has mild relaxant, cardio tonic, and chloretic (an agent, usually a drug, that stimulates the liver to increase output of bile) properties (Bhardwaj et al., 2010). The bark that is removed from the young branches is commonly used as a syphilis treatment (Upadhyay et al., 2007). The powdered bark is mixed with hot milk and used to induce abortions for a few days. Pinus leaf extract is used to crush its seeds in order to treat haemorrhoids (Ch et al., 2006). T. undulata leaves contain strong HIV inhibitors in the form of betulinic acid, ursolic acid, and oleanolic acid.

The medicinal properties of this plant are mentioned in all of the ancient Ayurvedic Samhitas. drawn from traditional ayurvedic literature. Tecomella is used to treat a variety of stomach issues. Charaka suggested powdered bark, its decoction, and its extract in clarified butter to treat intestinal worms, jaundice, enlarged spleen, anaemia, and urinary disorders (Khare 2004). Numerous ayurvedic preparations, such as Rohitakarista, Rohitakaghrita, Rohitakadyachoorna, Rohitakaloha, etc., are made from the bark of the Rohida plant. However, Rohitakaarishta (based on Bhaishajya Ratnaavali) is the only traditional over-the-counter medication prescribed for liver and spleen disorders, oedema, and anaemia; other preparations are not yet available (Jain et al. 2012).

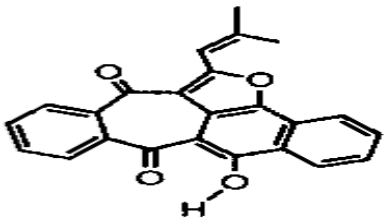
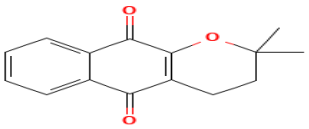
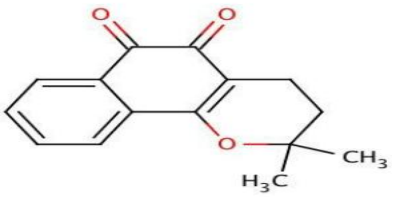
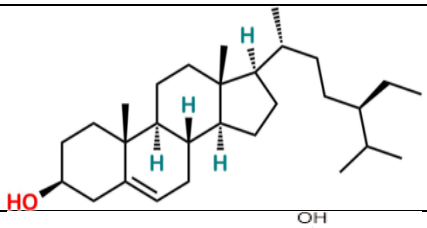
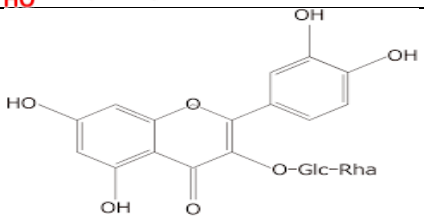
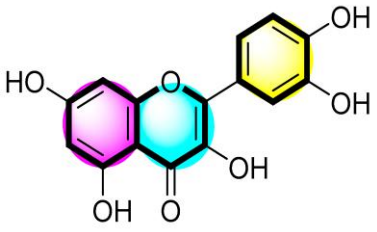
An Ayurvedic drug called Rohitakarista is used to treat gulma (localised abdominal swelling or tumour), udara (abdominal disease), and pliha (splenic disease). It contains trace amounts of other medicinal plants and is made from the stem and bark of T. undulata (Ullah et al. 2008). Rohitakarista increased total cholesterol, VLDL (very low density lipoprotein), HDL (high density lipoprotein), and decreased triglycerides in albino rats, according to Ullah et al. (2010).

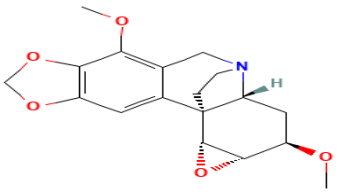
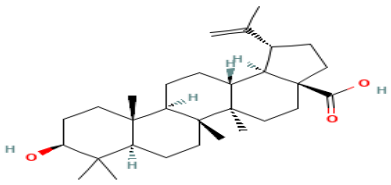
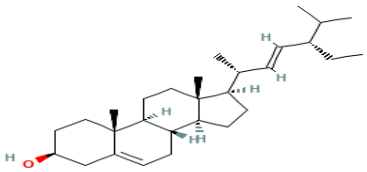
Phytochemistry

Because Tecomella undulata has a variety of pharmacological properties, researchers have focused on this plant to identify the phytoconstituents found in its various extracts. It has been possible to isolate and identify pharmacologically relevant compounds by using phytochemical studies to examine the composition of various plant extracts. For example, the heartwood contains radermachol (Singh et al. 2008), lapachol (Gupta et al. 1969), cluytylfrulate (Joshi 1974), β-lapachone (Joshi et al., 1986), α-lapachone (Joshi et al., 1977), and Dehydro-α-lapachone (Pandya et al 2012). Cirsili and cirsimaritin are found in the plant's leaves (Azam and Ghanim 2000). β-sitosterols (Pandey and Dasgupta 1970), iridoid glucosides (Verma et al. 1979), tecomelloside (Gujral et al. 1979), rutin, quercetin, luteolin-7-glycoside, and β-sitosterol (Taneja et al. 1975) are all found in the bark. Lapacol, tricontanol-1, β-sitosterol, tectol, veratric acid, 6O-veratryl catalposide, and quinines are all found in the root (Joshi et al., 1975; Joshi et al., 1977). Aphanamixin lactone and aphanamixolide are found in Tecomella undulata fruit

shells (Khare 2004). Linoleic acid (53%) and lauric acid (7.14%) are found in the seeds, tannin, and seed oil. Table 3 lists some significant phytochemical components along with their structure and function.

Table 3: Some Important Phytoconstituents, their Structure and Uses

S. No	Name	Use of Phytoconstituents	Structure
1	Radermachol	Anti-inflammatory	
2	α-lapachone	Anti-cancer	
3	β-lapachone	Anti-neoplastic	
4	β-sitosterol	Anti-inflammatory; Anti-pyretic; Anti-neoplastic; Immunomodulatory	
5	Rutin	Use to treat vascular system related diseases	
6	Quercetin	Anti-carcinogenic; Anti-bacterial; Anti-viral; Anti-inflammatory	

7	Undulatin	Tumour; Anti-septic	
8	Betulinic acid	Potent anti-human; Immunodeficiency; virus (HIV virus); Hepatoprotective	
9	Stigmasterol	Cancer therapy	

Source: Rohilla and Garg 2013.

Pharmacological Study

In recent years, many studies have examined the effects of Tecomella undulata. Traditional herbalists and healers have long used Tecomella undulata to improve the function of different body parts and treat illnesses in both humans and animals. By identifying the mechanisms and modes of action and confirming the therapeutic efficacy of plants or plant extracts in clinical trials, research has largely validated conventional experience and wisdom. The following are the different pharmacological activities (Fig 2):

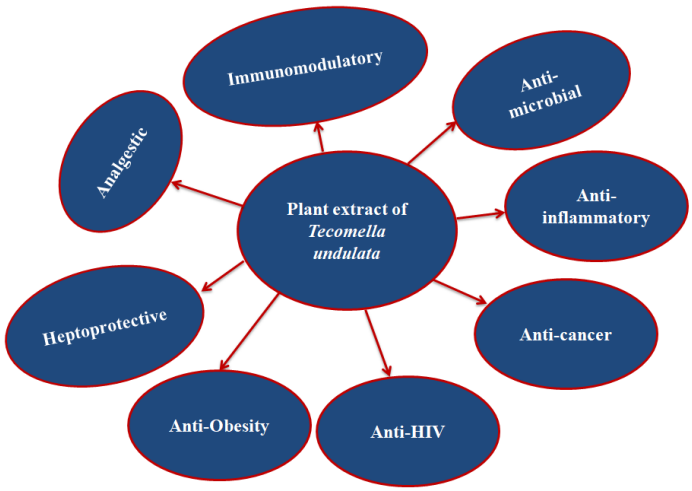


Figure 2: Pharmacological activity of *Tecomela undulata* plant extract

Anti-microbial Activity

Tecomella leaf and stem extracts have also been shown to be effective against the typhoid-causing Salmonella typhi (Gehlot and Bohra, 2005). Using the cylinder plate technique, another study shows that cold macerated alcoholic and actone extract can be used to combat both gramme positive and gramme negative strains (Singh and Suthar, 2023). While the acetone extract was effective against both B. subtilis and S. aurens, the alcoholic extract was effective against E. coli (Thanawala, 1993). The antimicrobial activity against five significant strains—S. epidermidis, B. subtilis, P. pseudoalcaligenes, P. vulgaris, and S. typhimurium—was examined by Parekh et al. (2005). They demonstrated how Tecomella methanolic extract inhibited S. epidermidis and B. subtilis.

Hepatoprotective Activity

Numerous research groups have reported on TU's hepatoprotective potential. The hepatoprotective potential of TU stem bark methanolic and ethanolic extracts was reported by Rana et al. (2008) and Khatri et al. (2009) using carbon tetrachloride and thioacetamide-induced hepatotoxicity in rats, respectively. Aspartate aminotransferase (AST), alanine aminotransferase (ALT), gamma-glutamyl transpeptidase (GGT), alkaline phosphatise (ALP), bilirubin, total protein, albumin, and cholesterol levels were all significantly reduced after oral administration of TU extracts, according to both authors' findings. Additionally, TU supplementation significantly improved hepatic glutathione, decreased hepatic malonaldehyde levels, and improved liver histopathology.

Using rats that had been given paracetamol to induce hepatotoxicity, Patel et al. (2011) assessed the hepatoprotective potentials of the methanol insoluble fraction and the chloroform, acetone, and methanol soluble fractions of the ethanolic extract of TU bark. Significant hepatoprotective activity against paracetamol-induced hepatic damage was demonstrated by the methanol soluble fraction, as demonstrated by the normalisation of significantly elevated levels of AST, ALT, ALP, and total bilirubin; a decrease in total protein; an increase in wet liver weight and volume; an increase in thiopentone sodium-induced sleeping time; and nearly normal histopathology.

Singh and Gupta (2011) [31] reported the first report on the hepatoprotective potential of TU leaves using a methanolic extract against alcohol and paracetamol-induced hepatic damage in rats. They found that oral pretreatment with TU extract (100 or 200 mg/kg) for 15 days prevented the increase in hepatic lipid peroxidation brought on by alcohol and paracetamol treatments, as well as the elevation of serum AST, ALT, ALP, GGT, and total bilirubin and the decrease in hepatic antioxidant enzyme activity levels. Additionally, TU extract pre-treatment prevented necrotic cell death and greatly reduced alcohol and paracetamol-induced hepatocyte damage. According to Goyal et al. (2012), an ayurvedic formulation called Rohitakaghrita, which contains TU along with four other plants, has the ability to protect the liver from the toxicity caused by paracetamol.

Serum AST, ALT, ALP, and bilirubin levels were considerably reduced when Rohitakaghrita (3.6 and 7.2 g/kg, p.o. daily) was taken orally for seven days, and then paracetamol (3 g/kg, p.o.) was administered on the third and fifth days. Rats given TU showed further reductions in hepatic lipid peroxidation, improvements in glutathione, catalase, and Na+-K+ ATPase activity, and a subsequent improvement in liver histopathology. The hepatoprotective properties of TU and its application in herbal formulations and traditional medicines are suitably supported by these data.

Anti-inflammatory Activity

Ahmad et al. (1994) used carrageenan-induced rat paw oedema as an experimental model to assess the anti-inflammatory properties of Tecomella undulata whole plant methanolic extract. According to the authors, paw oedema volume was significantly decreased in a dose-dependent manner by oral administration of TU extract at doses of 300, 500, or 1000 mg/kg bodyweight. These outcomes were similar to those of rats given acetylsalicylic acid. Rat paw oedema caused by carrageenan and granuloma caused by cotton pellets are both significantly reduced by T. undulata bark. According to Goyal et al. (2010), the activity was comparable to that of the common medication indomethacin. The anti-inflammatory properties of Tecomellaundulate's whole plant methanolic extract were recently reported by Suthar and Singh (2023).

Anti-cancer Potential

Earlier, Ravi et al. (2011) reported the anti-cancer potential of TU stem bark chloroform extract. The antitumor potential of TU extract was investigated utilising the chronic myeloid leukaemia cell line (K562). The study was additionally expanded to standardise the extract utilising quercetin as a

biomarker. The results unequivocally demonstrated substantial growth inhibition by TU in K562, COLO-205, MDA-MB231, and HepG2 cells within a dosage range of 10-100 µg/ml. Moreover, the effect was determined to be dose-dependent, exhibiting an IC50 of 30 µg/ml, alongside the activation of FAS, FADD, caspase 8, caspase 3/7, and the fragmentation of DNA. The authors effectively demonstrated the potential antitumor properties of TU extract, thereby corroborating the traditional assertion.

In a prior study, Savjiyani et al. (2012) assessed the anticancer potential of a polyherbal formulation (SJT ONC) derived from the extracts of the stem bark of Tecomella undulata, Bauhinia variegata, Oroxylum indicum, and the leaves of Indigofera tinctoria, utilising both in vitro and in vivo experimental models. SJT ONC-1 (1000 µg/ml) exhibited considerable cytotoxicity towards Caco-2 and MCF-7 cell lines. Additionally, administering SJT ONC-1 (300 mg/kg, p.o.) to rats subjected to a high-fat diet and treated with dimethylbenz anthracene for 12 weeks led to a substantial decrease in mammary tumour volume. The outcomes were similar to the standard medication 5-fluorouracil.

Immunomodulatory Activity

A weak or failing immune system can be effectively treated with a herbal combination of TU, Moringa oleifera, Boerhaviadiffusa, Onosmabracteatum, Bauhinia variegata, Spheranthus indicus, Chlorophytum borivilianum, Ficus racemosa, and Cyperus rotundus. This herbal preparation is especially helpful in preserving the immune system's normal physiological functions, controlling immunological functions, and preventing any abnormalities brought on by mild immunological imbalances. It has been shown to be effective in preventing cancers brought on by compromised immune systems.

It has been shown to strengthen the immune system in people with HIV and AIDS through the following mechanisms: (A) by promoting the production of growth factors that are responsible for the production of immune apparatus cells, such as lymphocytes, macrophages, langerhans cells, histiocytes, etc.; (B) by boosting the immune response by producing new cells and replacing the immune system's aging and functionally incompetent cells; (C) by absorbing free radicals produced by the metabolism of cancer cells, antiretroviral metabolism in cells of people with HIV or AIDS, and during the aging process (i.e. antioxidant effect); and (D) by encouraging the immune apparatus to produce antibodies and immune complexes (i.e. immunostimulatory effect).

Its chemo protective or radio protective properties in patients undergoing cancer therapy are well documented. In this case, it can be used as an adjuvant to conventional treatments to reduce the adverse side effects of these therapies. Also, herbal preparations of TU show radio sensitizing and chemo sensitizing properties in cancer patients wherein, the tumour becomes more sensitive to the conventional anticancer therapy. This also helps in effectively reducing the required dosage of these therapies in order to achieve the prescribed therapeutic effects, thereby reducing and alleviating the powerful and devastating adverse side effects (Managoli 2008). Recently, Choudhary, 2011 evaluated immunomodulatory activity of TU stem bark ethanolic extract using experimental models of cellular and humoral immunity. Authors demonstrated that, oral administration TU extract (100 mg/kg) in mice prevented cyclophosphamide induced suppression of humoral response and potentiated the delayed-type hypersensitivity reaction induced by sheep red blood cells (SRBC). These results were comparable with vitamin E treated mice.

Anti HIV Potential

Azam has reported that leaves of Tecomella undulate contain some phytoconstituents, which have anti-HIV potential. Octadimethyl succinate derivatives of oleanolic acid and betulinic acid have been reported to be 24 times more active as compared with Zidovudine drug (most frequently used drug to check spread of HIV). However, further studies are required to know the underlying mechanism of Tecomella undulata in curing AIDS and formulation of this herb (Azam 1999).

Anti Microbial Activity

According to Parkash et al., only the methanolic extract of the plant showed a noticeable antimicrobial effect against selected microbes. Danya et al. (2012) used the whole plant and tested its antimicrobial activity using disk diffusion and minimum inhibitory concentration (MIC) methods. Their study found that *T. undulata* showed strong effects against bacterial strains like *Salmonella paratyphi*, *S. paratyphi*-A, *Bacillus subtilis*, and *Bacillus thuringiensis*, as well as fungi such as *Aspergillus niger* and *A. flavus*. In another study, Suganya et al. (2011) looked at the antibacterial activity of nanofiber mats containing a crude bark extract of *T. undulata*. The extract was prepared using a chloroform and methanol mixture (4:1). These mats, made from PCL/PVP (polycaprolactone/polyvinylpyrrolidone), were

tested against common bacterial strains like *Pseudomonas aeruginosa* (MTCC 2297), *Staphylococcus aureus* (ATCC 933), and *Escherichia coli* (IP-406006). The results showed that the mats were effective in stopping the growth of these bacteria.

Anti-diabetic and Anti-oxidant

Kumar et al. (2012) studied the anti-diabetic effects of an ethanolic extract of *Tecomella undulata* using a type-2 diabetes model in rats. Diabetes was induced in the rats using streptozotocin and nicotinamide. The extract significantly reduced blood glucose levels in the oral glucose tolerance test. Additionally, it helped improve other diabetic markers such as cholesterol levels, liver glycogen content, and glycosylated hemoglobin. The study also assessed antioxidant activity using standard kits to measure malondialdehyde (MDA) and glutathione levels. The results suggested that the extract has both anti-hyperglycemic and antioxidant properties.

Conclusion

The current investigation concluded that *Tecomella undulata* (Rohida) is a medicinally and ecologically important tree species in the arid and semi-arid zones of India, yet it is now threatened in Rajasthan due to overexploitation and regeneration constraints. The ethnomedicinal record, together with modern pharmacological studies, supports a broad spectrum of bioactivities—antiulcer, anti-inflammatory, laxative, antidiabetic, anticoagulant, antioxidant, antimicrobial, and potential antiviral (e.g. anti-HIV) effects. Key classes of phytoconstituents such as triterpenoids (e.g. betulinic acid, oleanolic acid, ursolic acid), sterols (β-sitosterol, stigmasterol), flavonoids (quercetin, kaempferol), and possible naphthoquinones contribute to these biological effects.

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