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A Phyto-Pharmacological review on *Shorea robusta* Gaertn. (SAL)

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Abstract

Shorea robusta Gaertn. (Sal) has been commonly used in Indian traditional medicine for treatment of various ailments such as circulatory, digestive, endocrine, respiratory and skeletal systems as well as in infectious diseases. The present review on its botany, traditional uses, pharmacological activities and phytochemistry which provides preliminary information to explore its therapeutic potential and future research opportunities. The phytochemical studies have shown the presence of many secondary metabolites belonging to terpenoids, flavonoids, carbohydrate, lignans, phenols and sterols. Crude extracts and isolated compounds from *Shorea robusta* show a wide spectrum of pharmacological activities, such as anti-inflammatory, anti-obesity, antimicrobial, wound healing, antinociceptive, kairomonal, immunomodulatory anti-pyretic & analgesic activities. Many studies have provided evidence for various traditional uses. The present review is, therefore, an effort to give a detailed survey of the literature on its traditional, pharmacognosy, phytochemistry and pharmacological uses. The outcome of these studies will further expand the existing therapeutic potential of *S. robusta* and provide a convincing support to its future clinical use in modern medicine.

Keywords Ayurveda, Shorea robusta, Phytochemistry, Sacred tree, Traditional uses

INTRODUCTION

India has a long tradition of the use of drug derived from plants in the Ayurvedic system of medicine. It has been stated that over 2000 Plants grow in India which have medicinal properties in which maximum species are found in wild state and some are cultivated. India is a varietal emporium of the medicinal and aromatic plants (MAPs) and we have well-established local healthcare tradition still relevant in indigenous healthcare system (Kapoor, 2012; Attrey *et al.* 2012). About three quarters of the world's population relies on plants and plant extracts for health care. The use of medicinal plants in the Indian subcontinent can be

traced back to the Vedic period. The texts mentioning the uses of different medicinal plants are the Rigveda(written between 4500 and 1600 BC), the Atharveveda (2000–1000 BC), the Charaka Samhita (~900 BC) and the Sushruta Samhita (~600 BC); these texts are written in Sanskrit (Tomar 2006; Sati et al. 2010; Dev 1999 and Balasundaram et al. 2011). *Shorea robusta* Gaertn. f. (Dipterocarpaceae) is a moderate deciduous tree commonly known as Sal. It is widely distributed in tropical regions of India, Indonesia, Malaysia and Philippines. The Sal tree is widely distributed in India, covering approx. 13.3% of the total forest area in the country from the plains upto 900-1700-meter altitude covering part of North, East and Central India. In the North it extends from Punjab, Himachal Pradesh to Haryana states through the sub Himalayan tracts, outer Himalayas to Assam and Tripura states covering Garo, Khasi and Jaintia hills. In the East it is distributed from western Bengal. Orissa upto Vishakhapattanam in south and through greater part of south eastern Madhya Pradesh up to Chindawara and Hoshangabad districts in the west. Also distributed in Nepal and Bhutan (Adlakha et al. 2014). It is commonly knownas Sal tree in English, Sakhwa or Sal in Hindi, Chiraparna in Sanskrit, Guggilu in Marathi, Gugal in Telgu and Sakhu in Bengali (Soni et al. 2013).

Shorea robusta is a large, deciduous tree up to 50 m tall and with a dbh of 5 m; these are exceptional sizes, and under normal conditions *S. robusta* trees attain a height of about 18-32 m and girths of 1.5-2 m. Crown is spreading and spherical in shape. Bark is of dark brown colour and 2.5 cm thick, with deep vertical furrows. old bark of matured trees is thicker and quite rough with having deeper furrows and are grayish, reddish brown to dark brown in colour and provides effective protection against fire. The tree develops a long taproot at a very young age. On tapping the trees exudes a white liquid an oleoresin which turns brown on drying. Heartwood is coarse, cross grained and pale brown to dark reddish brown in colour. Leaves are simple, shiny, glabrous, about 10-25 cm long and broadly, stout, leathery, shining, alternate, entire, oval at the base, with the apex tapering into a long point; new leaves are reddish, soon becoming delicate green. Flowers are pale yellow or cream coloured, in lax, terminal or axillary panicles, velvetty pubescent. Fruit are 1-1.5 cm long, ovoid, reddish to pale yellowish green slightly fleshy, indehiscent, with wing like persistent sepals, 5-7 cm long, wings linear, 10-nerved and obtuse. Plant bears young foliage and flower in March-April fruiting begins during summer season. Generally, flowers appear in March and fruits in June (Sharma and Vigyana 2006).

TRADITIONAL USES

Ayurveda has declared that the drug Shala having Kashaya rasa, Rukshaguna, Sheetavirya, Katuvipaka and it pacifies Pitta and Kapha, so prevent the formation and growth of Krimis (Chunekar and Nighantu 2010). The leaves and bark are used to treat wounds, ulcers, leprosy, cough, gonorrhea, earache and headache (Warrier et al. 1994). The fruits are useful in tubercular ulcers, seminal weakness, burning sensation and dermopathy (Warrier et al. 1994). The oleoresin exuded from the plant has astringent, carminative and stomachic properties. It is useful in vitiated conditions of pitta, wounds, ulcers, neuralgia, burns, fractures, fever, diarrhea, dysentery, splenomegaly, obesity and

burning of the eyes (Warrier et al. 1994). In Unani medicine, the resin is used for treating menorrhagia, enlargement of spleen and for relieving eye irritation. In Ayurveda, it is used with honey or sugar in treatment of dysentery, bleeding piles, gonorrhea, for weak digestion and it is also suggested for ulcers, wounds and menopausal disorders by Siddha practitioners (Wani et al. 2012). Earlier pharmacological studies confirmed its anti-bacterial (Wani et al. 2012), anti-aging (Kuppusamy and Uthamarayan 1998), analgesic, anti-inflammatory (Alluri 2005) and wound healing (Wani et al. 2012) effects.

PHARMACOGNOSTICAL CHARACTERISTICS

Macroscopical evaluation of resin

Resin of Sal is of irregular and often cylindrical in shape. There is variation in size, all are of different sizes. The colour of resin varies from dark brown to pale amber or yellow and red. Resin is generally tasteless but sometimes the taste resembles the taste of turpene.

MICROSCOPICAL

Transverse Section of Root:

Phloem fibers and xylem fibers are present. Xylem fibers consist of large vessels. Cork cambium is seen to arise on the outer most layer of the cortex. Phloem and xylem are transverse by uniseriate medullary rays. There is presence of tracheid and lignified parenchyma. Pith is also present.

Transverse Section of Young Stem:

Covering trichome is of stellate type due to elongation of epidermal cells. Tracheid, and parenchyma are present. Medullary rays are less prominent. Xylem is having vessels. Chlorenchyma is followed by collenchyma's cells.

Transverse Section of Midrib of lamina:

Transversely elongated parenchymatous cells are externally covered by thick cuticle. Bundle sheath is present between palisade and spongy parenchyma. Xylem tissue is present above the phloem in vascular strand. Some cells possess microsphenoidal crystal of calcium oxalate as sandy masses.

Powder:

Powder was greyish brown in colour and microscopical examination showed fragments of cork cells, stone cells, thick walled fiber patches of adjacent cells of fibers with prismatic crystals of calcium oxalate, medullary rays with interlocking arrangements.

PHYSICAL CONSTANTS

Quantitative Analysis of *Shorea robusta* (Datta et al. 2011)

Resin reveals that Loss on Drying is 8.29 %, Total Ash value is 0.6108%., the average percentage of acid insoluble ash is 0.9820 % the average percentage of water-soluble ash is 0.0580 % Density1% is 1.00989 gm/cm3 and it has acidic pH.

Bark reveals that Loss on Drying is 9.86 %., Total Ash value is 12.2486%., the average percentage of acid insoluble ash is 2.22% the average percentage of water-soluble ash is 3.886% Density1% is 1.00942 gm/cm^3 and it has alkaline pH.

Root reveals that Loss on Drying is 6.72 %., Total Ash value is 2.2460%., the average percentage of acid insoluble ash is 1.2720%. The average percentage of water-soluble ash is 0.5870% Density1% is 1.0100 gm/cm^3 and it has acidic pH.

Leaf reveals that Loss on Drying is 7.40 %., Total Ash value is 6.3337%., the average percentage of acid insoluble ash is 1.6650% the average percentage of water-soluble ash is 2.4660% Density1% is 1.0104 gm/cm and it has acidic pH.

PHYTOCHEMISTRY

Root bark led contains Asiatic acid **(1),** 3,25-epoxy-1,2,3,11-tetrahydroxyurs-12-en-28-oic Acid **(2),** 3,25-epoxy-1,2,3-trihydroxyurs-l2-en-28-oic Acid **(3)**, Phayomphenol **(4)** and 3,7-dihydroxy-8-methoxyflavone 7-O-α-L-rhamnopyranosyl-(1→4)-α-L-rhamnopyranosyl-(1→6)-β-D-glucopyranoside (Adlakha 2013) **(5)** and also contains ursonic acid **(6)**, oleanane **(7)** and shoreaphenol (Sharma et al. 2014; Harbone 1999) **(8)**. Seed contains hopeaphenol **(9)**, leucoanthocyanidin **(10)**, and 3, 7-dihydroxy-8-methoxyflavone7-O-α-l-rhamnopyranosyl-(1→4)-α-l-rhamnonopyranosyl (1→6)-β-d-glucopyranoside (Patra et al. 1992) and also contains some acids like corilagin, ellagic **(11)**, chebulinic, gallic, phenolic, shorbic acid (Prakash and Rao 1999) **(12)**. Heartwood contains germacrene-D (Sastry and Vijnana 2005) **(13)**. From mature leaves isolation of β-amyrin **(14)**, friedelin **(15)**, β-sitosterol **(16)**, pheophytin-α **(17)**, and dihydroxyisoflavone **(18)** is reported (Kaur et al 2001). Essential oil present are p-cymene **(19)**, tetrahydro-gamma-cadinene, cadalene (Prakash and Rao 1999) **(20)**. In whole plant presence of leucoanthocyanidin **(10)**, hopeaphenol **(9)**, triterpenoids and a terpene alcohol, furfural, monomethylether, dimethylether of homocatechol **(21)**, alkybenzene derivatives, pentosans, lignan, tannin, amino acids, fatty acids, triterpenoids (Prakash and Rao 1999), ursolic acid and α-amyrenone **(22)**, α & β-amyrin **(14)** are reported (Chauhan et al. 2002; Hota and Bapuji 1993). From the resin, isolation of two triterpenoids namely 3,25-epoxy-1,2,3,11-tetrahydroxyurs-12-en-28-oic acid **(2)** and 3,25-epoxy-1,2,3-trihydroxyurs-l2-en-28-oic acid are reported (Bapuji 1993) **(3)**. The structures are presented in Figure-1.

PHARMACOLOGICAL PROPERTIES

Free radical scavenging and antioxidant activities

The antioxidant avctivity of *Shorea robusta* on hepatocytes was evaluated by MTT assay [(3-(4, 5 dimethylthiazole –2 yl)-2,5 diphenyl tetrazolium bromide) assay]. The percentage viability of the hepatocytes was carried out. The isolated hepatocytes were cultured in Ham's F12 medium, supplemented with 10% newborn calf serum, antibiotics, dexamethasone and bovine insulin. The cell suspension was incubated at 37 in °C for 30 min in a humidified incubator under 5% CO_2. After incubation of 24 hrs, the hepatocytes were exposed to the fresh medium containing CCl_4 (1%) along with different concentration of *Shorea robusta* (200 and 400µg/ml). After 60 min of CCl_4 intoxication, the oxidative stress markers were determined. The phytochemical screening revealed the presence of flavonoids, terpenoids, triterpenoids, polyphenol and tannins in Methanol extracts. The percentage viability of the hepatocytes was dose dependent. The entire variables tested i.e., antioxidant enzymes like SOD, CAT and GPx, reduced glutathione, vitamin-C and vitamin-E recorded a significant decline on CCl_4 intoxication. However, treatment with *Shorea robusta* extract restored the levels to near normal value, suggesting the therapeutic effect of *Shorea robusta* to counter the oxidative stress. Among the two doses, the higher dose

has potential antioxidant activity (Mishra and Ahmed 1997). The ethanolic extract was screened for in vitro antioxidant activity by oxygen radical scavenging such as DPPH, total antioxidant assay, superoxide metal chelation and iron reducing power activity at different concentrations. Throughout the studies leaves extract showed marked antioxidant activity. The half inhibition concentration (IC_{50}) of plant extract and ascorbic acid in DPPH assay were 36.61µg/ml and 34.91 µg/ml, respectively. In superoxide anion scavenging assay, the half inhibition concentration (IC_{50}) of *Shorea robusta* was 43.20µg/ml and ascorbic acid were 31.62µg/ml, respectively. The formation of the ferrozine– Fe_2+ complex is interrupted in the presence of aqueous extract of *Shorea robusta*, indicating that have chelating activity with an IC_{50} of 40.74µg/ml and ascorbic acid was 30.96µg/ml, respectively. *Shorea robusta* leaf demonstrates a marked capacity for iron binding, suggesting their ability as a peroxidation protector that relates to the iron binding capacity. The antioxidant activity of the leaves extract may be due to the phytochemicals present in it. The antioxidant activity was found to be concentration dependent and may be attributed to the presence of bioflavonoid content in the leaves of *Shorea robusta*. Overall, the plant extract is a source of natural antioxidants which might be helpful in preventing the progress of various oxidative stress mediated diseases including aging (Suganya et al .2014).

Analgesic activity

Both aqueous and methanol extract (400 mg/kg) showed significant analgesic activity in acetic acid induced writhing and tail flick test. The dose of both extracts such as methanol and aqueous extract (200 and 400mg/kg i.p.) caused significant reduction of writhing and tail flick method in rats and mice by different ways (Mathavi and Nethaji 2014). 70% ethanolic extract of *S. robusta* resin (SRE) was evaluated for its analgesic activity by making use of different central and peripheral pain models. The extract (30, 100 and 300 mg/kg) produced significant central and peripheral analgesic effects, as is evident from increase in reaction time in hot plate and tail flick tests, inhibition in writhing counts in acetic acid-induced writhing test, inhibition of licking time in formalin-induced hind paw licking, increased pain threshold in paw withdrawal latency in carrageenan-induced hyperalgesia and increased paw withdrawal threshold in post-surgical pain (Chattopadhyay et al. 2012).

Anti-inflammatory activity

70% ethanolic extract of *S. robusta* resin (SRE) was investigated for its anti-inflammatory activity. Acute inflammation was produced by carrageenan-induced hind paw edema and sub-acute by cotton pellet-induced granuloma in male Wistar rats. Extract (100 and 300 mg/kg) produced a significant reduction in edema volume and decrease in granulation tissue formation in rats. Significant reduction in pyrexia was observed at all the dose levels of SRE i.e. 30, 100 and 300 mg/kg (Wani et al. 2012). The aqueous extract of *Shorea robusta* with a dose of 100, 200 & 500 µg/ml, was taken for the activity & compared with the standard Diclofenac doses of 20 & 40 µg/ml, in HRBC membrane stabilization model and same dose of extract was taken for activity & compared with Aspirin 200 µg/ml, using Heat induce hemolytic method. The

extract of 500 µg/ml showed good result in both models. As per phytochemical investigation the extract shows presence of flavanoids, tannins & saponins that may be responsible for its good anti-inflammatory activity (Wani et al. 2012). The methanolic and aqueous leaf extracts (200 and 400mg/kg i.p and p.o.) of *S. robusta* showed anti-inflammatory activity in carraganeen and dextran induced paw method and cotton-pellet-induced granuloma model in rats and mice (Nainwal et al. 2013).

Antipyretic activity

The ethanolic extract (70%) of *S. robusta* resin (SRE) was investigated for its antipyretic activity. The antipyretic activity of SRE was studied using Brewer's yeast-induced pyrexia in rats. The rats were divided into five groups with five animals in each group. Group I was treated with vehicle i.e. 1% v/v Tween-80 and served as control. Groups II to IV were treated with three different doses of SRE (30, 100 and 300 mg/kg orally). Group V was treated with standard drug etoricoxib (10 mg/kg orally). The results of this study demonstrated antipyretic activities of *S. robusta* resin and supported its traditional therapeutic use in fever (Jyothi et al. 2008).

Antinociceptive activity

A methanol extract of the dried leaves of *Shorea robusta* was investigated for antinociceptive activity. The extract (200 and 400 mg/kg, p.o) produced a dose dependent antinociceptive effect was also observed with hotplate device maintained at 550 °C, Acetic acid induced writhing, formalin induced paw licking, Tail clip and Tail flick models in mice. Two different dose levels exhibited a significant anti-nociceptive activity in different animal models of pain. In hot plate test, antinociceptive reaction towards thermal stimuli in mice is a well validated model for detection of opiate like analgesic drugs wherein pain response is from spinal origin (Nainwal et al. 2013).

Wound healing activity

The ethanolic extract of *S. robusta* resin (10 and 30 % w/w applied locally in excised and incised wounds) produced a dose-dependent acceleration in wound contraction and increased hydroxyproline content and tensile strength of wounds in rats. In excision wound model *Shorea robusta* resin extract (10% w/w) on 2nd, 4th and 6th day of wound healing caused significant ($P<0.01$, <0.001), <0.05, respectively) increase in wound contraction as compared to control group. Extract (30% w/w) on 2nd, 4th, 6th and 8th day of wound healing also produced significant ($P<0.01$, <0.001), <0.05, respectively) increase in wound contraction as compared to control group. Extract showed significant ($P<0.05$) dose dependent increase in wound contraction i.e. results were significantly different when comparison was made between 10 and 30mg/kg extract. In incision wound model, extract (10% and 30%) significantly, ($P<0.001$) increased the tensile strength as compared to the control group. Extract showed significant ($P<0.05$) dose dependent increase in tensile strength i.e. results were significant when compared to 30mg/kg extract (Wani et al. 2012). The effectiveness of wound healing activity and the possible mechanism of action of young leaf extracts of *Shorea robusta* and its isolated compounds as a topical formulation in three wound models in rats were determined. The prepared ointment containing extracts (2.5 and 5%, w/w), fractions (5% w/w) and isolated compounds (0.25% w/w) were

evaluated on excision, incision and dead space wound models in rats by the rate of wound closure, period of epithelialization, tensile strength, granulation tissue weight, hydroxyproline content and histopathology. The animals treated with the extracts and fractions (5%) showed significant reduction in wound area 96.55 and 96.41% with faster epithelialization (17.50 and 17.86), while the isolated compounds bergenin and ursolic acid heal the wound faster, but complete epithelialization with 100% wound contraction was evident with 5% povidone-iodine group on 18th post-wounding day. Moreover, the tensile strength of incision wound, granuloma tissue weight, and hydroxyproline content was significantly increased in both the extract and compound(s) treated animals. Furthermore, the tissue histology of animals treated with the isolated compound(s) showed complete epithelialization with increased collagenation, similar to povidone-iodine group (Duddukuri et al. 2011). To investigate wound-healing activity of *S. robusta* resin extracts and essential oil in rats Methanol extract (SRME), petroleum ether, benzene insoluble fraction of methanol extract (SRPEBIME), and essential oil (SREO) of *S. robusta* resin were incorporated in soft yellow paraffin (10% w/w) and applied once daily on incision and excision wounds of wistar rats. Framycetin ointment (1.0% w/w) was applied to the standard group. Tensile strength (on the 10th day), wound contraction, and scar area (on the 14th day) were recorded. On the 15th day, granulation tissues of excision wounds were analyzed for total protein, hydroxyproline, and hexosamine contents and activities of lipid peroxidation and super oxide dismutase (SOD). Histopathology of the wounds was also studied. SRPEBIME and SREO healed incision and excision wounds faster than plain ointment base and framycetin. Tensile strength of SRPEBIME-treated incision wounds was 53% higher than that of control animals. In excision wounds, wound contraction and scar areas were found to be 99% and 7.7 mm (SRPEBIME) and 71.7% and 21 mm (control). Protein and hydroxyproline contents were higher in SRPEBIME (20.8 and 3.5% w/w) and SREO (17.4 and 2.8% w/w) groups as against 9.95 and 1.48% w/w in control groups. Histopathology revealed complete epithelization and new blood vessel formation in SRPEBIME groups (Mukherjee et al. 2013).

Antimicrobial activity

The antimicrobial activity of methanolic and ethanolic extracts of *Shorea robusta* resin was checked for antimicrobial activity. The extracts were prepared by distillation method. The presence of alkaloid, saponin and terpenoid were confirmed by qualitative biochemical tests followed by TLC. Then comparative analysis of antimicrobial effects between those extracted compounds and available antibiotics in the market were tested in *Escherichia coli*, *Salmonella typhi*, *Pseudomonas sp.* and *Staphylococcus aureus* culture. Potent antimicrobial effects had been shown by both the extracts through procuring zone of inhibition on culture media which was nearly equivalent to the antibiotics applied. The four microbial species again respond against different antibiotics and parallel to ethanolic and methanolic extracts. Methanolic extract has high antimicrobial property against *E. coli* (3.5cm) and *S. typhi* (3cm) but is moderate to *S. aureus* (2cm) and *Pseudomonus sp*. (2.5cm). In contrary to that, ethanolic extract has high

antimicrobial property against *S. aureus* (3.4 cm) and *Pseudomonus sp.* (3.5 cm) but is moderate to against *E. coli* (2.4 cm) and weak against *S. typhi* (1.5 cm). So, the extract of *Shorea robusta* resin can be used as potent antimicrobial agent (Khan et al. 2016). Another study was done to evaluate the antimicrobial activity of *Shorea robusta* resin. Three different extracts viz. methanol, ethanol and toluene were used for determination of the activity. Three different sample of resin extract was taken with each sample having 3 different concentrations *i.e.* higher (100mg), medium (75mg), and lower (50mg). Then each sample was taken into study for evaluating the efficacy against five species of bacteria namely *Staphylococcus aureus, Streptococcus pyogenes, Pseudomonas aeruginosa, Escherichia coli, and Salmonella typhi*. Well method was adopted for assessment of antimicrobial activity of the drug obtained from *Shorea robusta*. Methanol extraction showed highest response in term of sensitivity (high zone inhibition), while the least sensitivity was observed with toluene extract. The methanolic extract, on increasing concentration *Streptococcus pyogen* showed slight high sensitivity (>12mm) inhibition Zone, *Staphylococcus aureus* showed moderate sensitivity (<12mm) inhibition Zone, *Escherichia coli* showed moderate sensitivity (<12mm) inhibition Zone, *Pseudomonas aeruginosa* showed no inhibition Zone and *Salmonella typhi* showed slight high sensitivity (>12mm) inhibition Zone. The ethanolic extract, on increasing concentration showed mild sensitivity (<9mm) inhibition Zone, *Staphylococcus aureus* showed slight high sensitivity (>12mm) inhibition Zone, *Escherichia coli* showed moderate sensitivity (<12mm) inhibition Zone, *Pseudomonas aeruginosa* showed no inhibition Zone and *Salmonella typhi* showed moderate sensitivity (<12mm) inhibition Zone. The toluene extract against *Streptococcus pyogen* showed mild sensitivity (<9mm) inhibition Zone, *Staphylococcus aureus* showed mild sensitivity (<9mm) inhibition Zone, on increasing concentration *Escherichia coli* showed moderate sensitivity (<12mm) inhibition Zone, *Pseudomonas aeruginosa* showed no inhibition Zone and *Salmonella typhi* also showed no inhibition Zone (Banerjee et al. 2014). Floral parts of *Shorea robusta* was evaluated for its antimicrobial activity. The aqueous extract of floral parts of *Shorea robusta* (Dipterocarpaceae) was prepared with cold water maceration. Well diffusion method was employed to determine the effect of antibacterial potential against Gram positive bacteria viz. *Staphylococcus aureus* and *Bacillus subtilis* and Gram-negative bacteria viz. *Klebsiella pneumoniae* and *Serratia marcescens*. Aqueous extract of the plant has showed significant inhibitory activity on different bacterial species tested against penicillin as standard antibacterial agent. In the floral parts tested, it was found that the extract of gynoecia (*Staphylococcus aureus*- 14mm *Bacillus subtilis*- 13mm, *Klebsiella pneumonia*- 15mm, *Serratia marcescens*- 14mm) showed comparatively good inhibitory activity than that of the petal extract (*Staphylococcus aureus*- 12mm *Bacillus subtilis*- 12mm, *Klebsiella pneumonia*- 11mm, *Serratia marcescens*- 12mm). The activity may be due to the presence of tannins, flavonoids, steroids and cardiac glycosides (Duddukuri et al. 2011). Methanolic extract of *Shorea robusta* leaves were evaluated for antibacterial activity against *Staphylococcus aureus* and *Klebsiella pneumonia*. The antibacterial activity of

methanolic extract of *S. robusta* against *S. aureus* and *K. pneumoniae* was carried out, the results revealed that the methanolic extracts of *S. robusta* presented less inhibition activity against *S. aureus* (Zone of inhibition of 12mm for 750mcg/ml and 14mm for 1000mcg/ml) and it doesn't show any antibacterial activity against *K. pneumoniae*. The result confirms that *S. robusta* leaves have less potential against selected pathogen *i.e. S. aureus* and *K. pneumoniae* (Adlakha et al. 2013). Extract of various plant parts viz. bark, leaves, flowers and seeds of *Shorea robusta* were examined for the determination of antibacterial activity. Twelve bacterial pathogens consisting of four Gram + (*Bacillus cereus*, *Bacillus subtilis*, *Staphylococcus aureus* and *Streptococcus pneumonia*) and eight Gram- (*Enterobacter aerogenes*, *Escherichia coli*, *Klebsiella pneumonia*, *Proteus mirabilis*, *Proteus vulgaris*, *Pseudomonas aeruginosa*, *Salmonella paratyphi* and *Vibrio cholerae*). The ethanolic extracts of bark, leaf, flower and seed of *S. robusta* were tested for susceptibility against all the given pathogens adopting standard disc diffusion method in Nutrient agar medium. The concentration of 200µg/disc was taken for the extracts and also the control (streptomycin). All the plant parts exhibited activities all the tested microorganisms. However, they showed minimum inhibition zones against *B. Subtilis* and *P. aeruginosa*. The bark and seed possess higher antibacterial activities followed by leaf and flower. Moreover, leaf exhibited considerable sizes of zones against *S. aureus* and *S. faecalis*. The higher antibacterial activities exhibited by the seed validates its ethnic usage against diarrhoea, dysentery and gastritis (Archana and Jeyamanikandan 2015).

Anti-Obesity activity

Anti-obesity effect of hydro-alcoholic extract of *Shorea robusta* (HASR) leaves on monosodium glutamate induced obesity in albino rats. Monosodium glutamate is used to induce obesity for 7 days along with normal diet and obtained obese rats were treated with *Shorea robusta* in a dose of 200, 400 and 600mg/kg p.o for next 41days. Physical parameters such as body weight, various organs and adipose tissue weight and various biochemical parameters like serum glucose, triglyceride, cholesterol, LDL-C, HDL-C, VLDL-C, atherogenic index, SGPT and SGOT were evaluated and compared with both normal control and obesity control groups. From result, it was concluded that hydroalcoholic *Shorea robusta* leaves extract is a potential drug which can be used for treatment of obesity and favours the correction of disturbed lipid profile (Marandi et al. 2015).

Antidiabetic activity

A study was done to determine the anti-diabetic activity of ethanolic extract of bark of *S. robusta* in alloxan induced diabetic rats. The bark powder of *S. robusta* was extracted with different solvent. Ethanol extract (200 mg/kg and 400 mg/kg body weight) was used for the study. Oral administration of ethanol extract of the bark of *S. robusta* in alloxan monohydrate (150 mg/kg) induce diabetic rats for 14 days showed in reduction in blood glucose level and biochemical parameter is dose dependent manner. The extracts in two different doses also prevent decrease in body weight. Oral administration of 200 mg/kg and 400 mg/kg in glucose tolerance test shows significant hypoglycemic activity and other biochemical parameter like, creatinine, cholesterol levels and blood

urea were estimated which shows significant results (Supriya et al. 2012). 95% ethanolic extract and their respective chloroform and n-butanal fractions of *S. robusta* leaves were evaluated for anti-diabetic activity. The test drug was administered for 21 days at a four different dose level 100, 200 mg/kg for ethanolic extract and 100, 100mg/kg each of two successive fractions (chloroform and n-butanol) made in aqueous and given by orally. Body weight, urine sugar was analyzed before and after treatment of extract/fractions while serum glucose was analyzed every week and lipid and lipoprotein profile from serum was analyzed after 21 days. The ethanolic extract/fractions of *S. robusta* leaves significantly prevented loss of body weight and reduce urine sugar. The results indicated that the ethanolic extract/fractions produced significant ($p < 0.001$) in biochemical parameter (Diptanu et al. 2015).

Immunomodulatory activity

The ethanolic extract of *Shorea robusta* bark was administered p.o. (orally) to mice at a dose of 100mg and 300mg/kg body weight per day for 14 days. In this study, *S. robusta* bark extract administrated rat models at 300mg/kg per day, i.p showed significant effect in stimulating immunomodulatory response, thus *S. robusta* bark is an effective natural health product for modulating immune system (Ravichandiran et al. 2015).

Kairomonal activity

The attractant (kairomonal) property of some compounds isolated from bark of *S. robusta* against its dreaded pest Sal borer, *Hoplocerambyx spinicornis*, in laboratory. Extract of the bark and its various isolates were prepared by standard procedure and subjected to bioassay. Behaviour exhibited by the beetles, viz., orientations, walking movement, antennal activity, visits to the test compound treated surface, biting and feeding attempts to the particular compound and number of beetles attracted has been recorded. They showed positive behaviour about the parameters discussed above against the bark extract as well as other isolated compounds. The chemical analysis of the compounds exhibiting the kairomonal property has also been performed (Kalaiselvan and Gokulakrishnan 2012).

Conclusion

From this review paper, the various actions of *Shorea robusta* as an effective anti-oxidant, analgesic, anti-inflammatory, anti-pyretic, anti-nociceptive, wound healing, anti-microbial, anti-obesity, anti-diabetic, imumno-modulatory and kairomonal activity has been proved. The plant has been in use for a long period of time without any documented serious adverse effects. The detailed information presented in this review provides evidence for its phytochemical, pharmacological & traditional uses. The outcomes of such future studies will provide promising sources of phytochemicals that will have huge potential for the pharmaceutical industry.

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