Ethnomedicinal Plant Sonapatha: Oroxylum indicum

Subjects: Pharmacology & Pharmacy

Contributor: Ganesh Chandra Jagetia

Oroxylum indicum, Sonapatha is traditionally used to treat asthma, biliousness, bronchitis, diarrhea, dysentery, fevers, vomiting, inflammation, leukoderma, skin diseases, rheumatoid arthritis, wound injury, and deworm intestine.

Keywords: Oroxylum indicum ; ethnomedicine ; antioxidants ; NF-κB ; COX-2 ; p53

1. Introduction of Pharmacological Activities

Sonapatha has shown various pharmacological activities in different study systems in vitro and in vivo as listed below.

2. Free Radical Scavenging and Antioxidant Activities

Table 1 lists the free radical scavenging ability of various extracts of Sonapatha. The estimation of antioxidant activity by reduction in Mo^{+4} to Mo^{+5} showed that petroleum ether, benzene, chloroform, ethanol, and aqueous stem bark extracts of Sonapatha dose dependently increased the antioxidant activity, and the highest antioxidant potential was detected for the chloroform followed by ethanol extract, whereas the petroleum ether extract was the least active [1]. The methanol extract of different parts of Sonapatha also scavenged hydroxyl, nitric oxide, superoxide, and DPPH free radicals in vitro [2]. The leaves of Sonapatha extracted in petroleum ether, chloroform, ethanol, and water inhibited the formation of DPPH, hydroxyl, nitric oxide, and superoxide radicals concentration dependently, where the ethanol extract was most potent. The reducing power assay further confirmed that the ethanol leaf extract of Sonapatha was more powerful than the other extracts [3]. Similarly, leaves of Sonapatha extracted in ethyl acetate, methanol, and water scavenged DPPH radical depending on their concentration, and the ethyl acetate extract was most potent followed by methanol and water extracts [4]. The hexane, chloroform, ethyl acetate, and water extracts of stem bark of Sonapatha showed a concentration-dependent inhibition of DPPH radicals, and the ethyl acetate extract was more effective than the other three extracts [5]. The petroleum ether, dichloromethane, and methanol extracts of Sonapatha have been found to scavenge DPPH, and superoxide radicals and possessed Fe^{3+} reducing potential. The methanol extract was more potent than the other two extracts [6]. The radical scavenging activity of chloroform, ethanol, and aqueous extracts of the stem bark of Sonapatha showed that it inhibited DPPH, superoxide anion, hydroxyl, and nitric oxide free radicals in a concentration-dependent manner, and 200 µg/mL of chloroform and ethanol extracts scavenged the DPPH radicals to the maximum extent. This concentration for hydroxyl radical inhibition was 6000 and 8000 µg/mL for chloroform and ethanol extracts, respectively. The highest scavenging of superoxide anion radical was observed at a concentration of 2500 µg/mL for both chloroform and ethanol extracts, whereas it took 20,000 µg/mL to inhibit the nitric oxide radical to the maximum extent. The ferric reducing power of different Sonapatha stem bark extracts increased depending on their concentration and a dose of 2500 µg/mL of all three extracts resulted in the maximum reduction in ferric iron [7]. The ethanol and aqueous extracts of Sonapatha seeds have been reported to inhibit DPPH radicals, whereas the fruit extracts were less effective than the seed extracts [8].

Table 1. Free radical scavenging and antioxidant activity of *Oroxylum indicum*.

Free radical scavenging and antioxidant activity of *Oroxylum indicum*.

Plant Part	Activity Type	Reference
Stem bark	Antioxidant	[1]
Root/root bark, stem/stem bark, leaf, fruit	Hydroxyl, nitric oxide, superoxide, DPPH radical scavenging	[2]
Leaf	DPPH, nitric oxide, superoxide, hydroxyl radical scavenging, reducing power	[3][4]

Plant Part	Activity Type	Reference
Stem Bark	DPPH, nitric oxide, superoxide, hydroxyl radical scavenging, reducing power	[1][5][6][7]
Seed	DPPH	[8]

3. Anti-Inflammatory and Analgesic Activities

The 50 µg/mL of dichloromethane root extracts of Sonapatha resulted in 100% inhibition of leukocyte lipoxygenase activity indicating its anti-inflammatory potential [9]. The aqueous leaf extract of Sonapatha has shown anti-inflammatory activity in carrageenan-induced rat paw edema test where 300 mg/kg body weight (b. wt.) extract was found to be superior over 150 mg/kg b. wt. [10]. A similar effect has been reported for the Sonapatha root and stem bark decoction in water that reduced the carrageenan-induced rat paw edema [11]. The rats treated with aqueous root extract of Sonapatha at a dose of 100, 200 and 400 mg/kg b. wt. for seven or four days significantly inhibited the induction of dinitrobenzene sulfonic acid-induced colitis [12]. The oral administration of 500 mg/kg b. wt. reduced acetic acid writhing, which was comparable to standard analgesic agent aminopyrine given at a dose of 50 mg/kg [13]. The aqueous extract of Sonapatha has been reported to reduce mouse ear edema in an earlier study [14]. The ethanol extract of Sonapatha (250 and 300 mg/kg b. wt.) was evaluated for its anti-inflammatory and analgesic activities and 300 mg/kg ethanol extract reduced mice ear and paw edema and also exerted analgesic effect to the maximum extent [15]. The hydroalcoholic extract of Sonapatha stem bark extract exerted anti-inflammatory activity on carrageenan-induced rat paw edema [16]. The Sonapatha extracted in methanol and given at a dose of 100, 200, and 400 mg/kg b. wt. has been reported to reduce carrageenan-induced rat paw edema depending on its dose. The histological evaluation of rat paw showed reduced cell infiltration and suppressed inflammation in a dose-dependent manner [17].

4. Anti-Allergic and Antiasthmatic Effect

Allergic rhinitis and asthma are linked and affect 40% of the world population. They reduce the quality of life and performance and their prevalence has been increasing in the population throughout the world [18]. The studies on the antiallergic and antiasthmatic effect of *Oroxylum indicum* are scanty. The antiallergic and anti-asthmatic effects of oroxylin A extracted from Sonapatha have been studied in female Balb/c mice and cultured rat RBL-2H3 mast cells. The rat RBL-2H3 mast cells sensitized with monoclonal anti-dinitrophenyl specific mouse IgE and then exposed to 0.1, 0.3, 1, 3, 10, and 30 µM oroxylin A reduced the antigen-induced degranulation in a concentration-dependent manner as indicated by the release of β-hexosaminidase. The maximum degranulation and β-hexosaminidase release were estimated at a concentration of 30 µM oroxylin A in RBL-2H3 mast cells. The female Balb/c mice were injected with 1 and 5 mg/ kg b. wt. oroxylin A intraperitoneally 30 before OVA administration to induce asthma inhibited the accumulation of eosinophils in bronchoalveolar lavage fluid of mice by 51% and 84%, respectively. The histologic observations of mice lungs revealed the accumulation of eosinophils around bronchioles whereas oroxylin A administration alleviated the eosinophils around bronchioles depending on its dose. The oroxylin A administration also reduced the OVA-induced mucin production in the mice lungs. The study on various cytokine expression revealed that oroxylin A suppressed the expression of IL-4, IL-5, and IL-13, INF-γ and IL-2 in the lungs of OVA administered mice, which may be responsible for its antiallergic and antiasthmatic activities in Balb/c mice [19].

5. Antimicrobial Activity

The antimicrobial activity of the dichloromethane extract of Sonapatha was studied against the Gram-positive and Gram-negative bacteria, and it was found to inhibit the growth of both the Gram-positive Bacillus subtilis and *Staphylococcus aureus* and the Gram-negative *Escherichia coli* and *Pseudomonas aeruginosa* bacteria and the fungi *Candida albicans* [9]. The dichloromethane extract of Sonapatha also inhibited the growth of dermatophytes and wood root fungi [20]. The root and stem of Sonapatha extracted in alcohol suppressed the growth of Klebsiella, *Escherichia coli*, Proteus, Pseudomonas, and *Staphylococcus aureus*, and the stem extract was found to be superior to the root extract [21]. The methanol extract of stem bark of Sonapatha has been reported to be active against *Bacillus cereus, Bacillus megaterium, Bacillus subtilis, Staphylococcus aureus, Sarcina lutea* (Gram-positive), *Escherichia coli, Pseudomonas aeruginosa, Salmonella paratyphi, Salmonella typhi, Shigella boydii, Shigella dysenteriae, Vibrio mimicus, Vibrio parahemolyticus* (Gram-negative), and the fungi *Saccharomyces cerevisiae, Candida albicans* and *Aspergillus niger* [22].

The petroleum, ether, dichloromethane, and methanol extracts of stem bark of Sonapatha were active against the *Klebsiella pneumoniae*, *Pseudomonas aeruginosa, Escherichia coli, Bacillus subtilis, Bacillus cereus,* and *Staphylococcus*

aureus bacteria and *Aspergillus flavus, Aspergillus fumigatus*, and *Macrofomina phaeolina* fungi [6]. The hydroalcoholic extract of stem bark of Sonapatha reduced the growth of *Bacillus cereus, Bacillus subtilis, Staphylococcus aureus,* and *Staphylococcus albus* bacteria [23]. The aqueous extracts of Sonapatha seeds and fruits have been reported to inhibit the growth of *Staphylococcus intermedius* and *Streptococcus suis* bacteria in a concentration-dependent manner and the aqueous extract was less effective. The seed extracts were more effective than the fruit extracts [24]. The stem bark of Sonapatha extracted in methanol, ethyl acetate and ethanol inhibited the growth of *Bacillus subtilis, Escherichia coli* (Gram-positive), and *Pseudomonas aeruginosa* (Gram negative), and the ethanol extract was found to be most potent [25]. The hexane, chloroform, ethyl acetate, and water extracts of stem bark of Sonapatha have shown antimicrobial activity against *Escherichia coli*, *Bacillus subtilis, Pseudomonas aeruginosa, Staphylococcus aureus,* and *Candida albicans*. The chloroform and ethyl acetate extracts were most effective than the hexane and water extracts [5]. The tender leaves of Sonapatha extracted in methanol inhibited the growth of *Pseudomonas aeruginosa* and *Bacillus subtilis* studied by zone inhibition and well methods, respectively [24]. The orlumin A isolated from the fruits of Sonapatha has shown the highest antibacterial activity against methicillin-resistant *Staphylococcus aureus* (MRSA) with a MIC value of 3.1 µg/mL [26].

6. Anthelmintic Effect

The methanol extract of Sonapatha stem bark has been tested against the anthelmintic activity in *Hymenolepis diminuta*. The artificially excysted juveniles and adult *H. diminuta* worms were treated with 10, 20, and 30 mg/mL of stem bark Sonapatha decoction. The exposure of juvenile worms to 30 mg/mL of Sonapatha bark extract resulted in worm mortality as early as 0.25 ± 0.00 h after treatment. The scanning electron microscopic examination revealed that the extract treatment led to wrinkled scolex, distorted integument, and eroded microtriches in both the juvenile and adult worms [27]. The in vivo study in *H. diminuta* infected Wistar rats revealed that administration of 1000 mg/kg b. wt. Sonapatha extract caused 79.3% reduction in eggs per gram of feces count and 70.8% reduction in worm counts indicating that it was more effective in killing juvenile worms than the adult worms [27]. A study of methanol extract of Sonapatha stem bark and aqueous fruit extracts was conducted against the killing of adult *Pheretima posthuma* earthworm. The exposure of *P. posthuma* to 10, 50, and 100 mg/mL of stem bark and fruit extracts of Sonapatha resulted in a concentration-dependent paralysis and death of earthworms depending on the concentration [28].

7. Hepatoprotective Effect

The hepatoprotective effect of petroleum ether, chloroform, ethanol, and aqueous extracts of Sonapatha leaves was studied against the carbon tetrachloride-induced liver toxicity. All four extracts protected the liver against the carbon tetrachloride-induced toxicity as indicated by a decline in the rat serum aspartate transaminase (AST) and alanine aminotransaminase (ALT) alkaline phosphatase (ALP) and total bilirubin levels. However, ethanol extract was found to be most effective than the other three extracts [3]. The administration of methanol stem bark extract of Sonapatha at a dose of 500 mg/kg b. wt. protected rat liver against the carbon tetrachloride-induced toxicity by reducing the serum AST, ALT, ALP, and total bilirubin levels. It also reduced carbon tetrachloride-induced rat liver damage and necrosis [29]. The hepatoprotective action of 100, 200, and 400 mg/kg b. wt. of aqueous root bark extract of Sonapatha was studied against the paracetamol-induced liver toxicity in Wistar rats, where the aqueous extract was found to reduce serum AST, ALT, and ALP levels in a dose-related manner, and their lowest activities were reported for 400 mg/kg extract. This was backed by histological examination where the aqueous Sonapatha root bark extract reduced the paracetamol-induced degenerative changes in the liver of Wistar rats [30]. The mouse treated with petroleum ether, ethyl acetate, methanol, and ethanol extracts of Sonapatha stem bark protected the liver against carbon tetrachloride-induced liver toxicity. The ethyl acetate extract was superior to other extracts as it reduced the pathological damage to the liver to a maximum extent followed by the higher reduction in AST, ALT, ALP, and total bilirubin levels in mouse serum than the other extracts [31]. The methanol-dichloromethane extract of the whole Sonapatha plant has been reported to protect liver explant and chronic liver damage in rats as indicated by a significant depletion in AST, ALT, and ALP levels in both explant and rat serum. Besides, the serum bilirubin level declined significantly. The histology of the liver showed mild hepatic swelling and a reduction in the carbon tetrachloride-induced hepatic injury [32]. The administration of 10, 50, and 100 mg/kg b. wt. aqueous-methanol extract of stem bark of Sonapatha reduced the acetaminophen-induced liver toxicity in a dose-dependent manner, where the serum levels of AST, ALT, and lipid peroxidation (LOO) were significantly low in Sprague-Dawley rats [33]. The aqueous and ethanol extracts of Sonapatha protected Wistar rats against the antitubercular drug AKT-4 induced hepatotoxicity significantly by alleviating the AKT4 induced increase in ALT, AST, lactate dehydrogenase (LDH), and total bilirubin levels. Additionally, the aqueous and ethanol extracts of Sonapatha significantly increased catalase, superoxide dismutase (SOD), and glutathione (GSH) levels, whereas LOO level declined significantly in the AKT-4 treated rat liver. AKT4 induced pathological alterations in the hepatocytes of the rat with distorted hepatic cords, degenerative, and necrobiotic changes, accumulation of fat globules in the hepatocytes with their swelling and hemorrhage, whereas treatment of rats

with aqueous and ethanol extracts of Sonapatha, showed no such histopathological changes in the liver [34]. The 70% ethanol extract of stem bark of Sonapatha reduced serum, ALT, ALP, γ-glutamyltransferase (GGT), and total bilirubin levels at different posttreatment days in the carbon tetrachloride treated Wistar rats [35]. The seed extract of Sonapatha has been reported to protect against the progression of nonalcoholic fatty liver disease into nonalcoholic steatohepatitis in vitro and in vivo by inhibiting the transcriptional activity of NF-κB and its phosphorylation and increasing the nuclear factor of kappa light polypeptide gene enhancer in B-cells inhibitor (IκB) level [36].

8. Gastroprotective Effect

The gastroprotective activity of 100 and 300 mg/kg b. wt. of 50% hydroalcoholic, petroleum ether, chloroform, ethyl acetate, and n-butanol extracts of root bark of Sonapatha were studied against ethanol-induced gastric damage. All extracts at a dose of 300 mg/kg showed a significant reduction in the ulcer index. The petroleum ether, n-butanol, and chloroform extracts were most effective when compared to ethyl acetate and hydroalcoholic root extracts. Likewise, these extracts of Sonapatha also reduced LOO and increased the activities of SOD, and catalase, and GSH levels, especially at a dose of 300 mg/kg in Wistar rats [87]. Treatment of 100 and 250 mg/kg of hexane and acetone stem bark extracts of Sonapatha had a mild to moderate protective effect against different models of gastric ulcerations. The isolated chrysin and compound 1 from the stem bark of Sonapatha were superior gastroprotective agents in pylorus ligation and cold restrain-induced ulceritis models in rats [40]. The butanol, petroleum ether, and ethanol extracts of stem bark of Sonapatha reduced the ethanol-induced gastric ulcers with an inhibitory index of 0.07±0.007 (99%), 0.27±0.011 (96%), and 0.87±0.044 (86%), respectively [72].

9. Cardioprotective Effect

The cardioprotective effect of 70% methanol extract of root bark of Sonapatha was studied in doxorubicin-treated Sprague Dawley rats. The oral administration of animals with 200 and 400 mg/kg b. wt. Sonapatha extract for 14 days protected rats against doxorubicin-induced cardiotoxicity. The methanol extract of Sonapatha led to normalization of Electrocardiogram (ECG), ST-segment depression, and QRS complex in the hearts of doxorubicin treated rats. The serum marker enzymes like creatinine phosphokinase (CPK), AST, and LDH were significantly reduced by methanol extract of Sonapatha. The assessment of LOO, GSH, glutathione peroxidase, (GPx), and SOD in the heart tissue revealed a significant decline in LOO and rise in the GSH, GPx, and SOD levels in the Sonapatha treated group when compared to doxorubicin treatment alone. Histopathologic evaluation revealed focal degeneration, fragmentation, disorganization of myofibrils, and necrotic changes in the heart tissue after doxorubicin treatment whereas Sonapatha extract administration reduced these changes [88].

10. Antidiabetic Effect

Administration of 300 and 500 mg/kg b. wt. of aqueous and ethanol extracts of Sonapatha for 21 days significantly reduced serum glucose levels in alloxan and dexamethasone-induced diabetes in Wistar rats [89]. Methanol extract of the heartwood of Sonapatha reduced the activity of α-glucosidase (GAA; an enzyme involved in carbohydrate digestion and glycoprotein biosynthesis, which is highly activated in diabetes) indicating its antidiabetic potential [41]. Similarly, hydroalcoholic extract (50% ethanol) of Sonapatha inhibited GAA activity in vitro. Sonapatha extract has been found to improve insulin sensitivity in cultured 3T3-L1 mature adipocytes. Oral administration of 250 mg/kg b. wt. of 50% ethanol extract of Sonapatha has reduced fasting blood glucose, low-density lipoprotein (LDL), and glycosylated hemoglobin (HbA1c) levels and elevated high-density lipoprotein (HDL) in streptozotocin-induced diabetic rat serum after 28 days post-treatment. Homeostasis model assessment-insulin resistance (HOMA-IR) index and quantitative insulin sensitivity check index (QUICKI) were also significantly reduced in Sonapatha treated diabetic rats after 28 days post-treatment [90]. The seeds of Sonapatha extracted in 90% ethanol inhibited the rat intestinal GAA activity. The administration of 50 and 250 mg/kg b. wt. of alcoholic seed extract of Sonapatha non-significantly reduced the fasting glucose level in alloxan-induced diabetic mice however, its combination with acarbose significantly reduced the fasting glucose level [91]. Similarly, 90% ethanol seed extract of Sonapatha at a dose of 50 and 200 mg/kg b. wt. in conjunction with acarbose inhibited glucose level in streptozotocin-induced diabetic mice significantly. The Sonapatha seed extract increased the antioxidative capacity by elevating GSH, SOD, and HDL followed by reduced LOO and LDL levels in prediabetic mice [92]. The administration of 300 mg/kg b. wt. of aqueous and methanol extracts of Sonapatha leaves reduced the glucose, total cholesterol, triglyceride, protein, urea, and creatinine levels in alloxan-induced diabetic rats [93]. Administration of 200 and 400 mg/kg b. wt. of 50% ethanol seed extract of Sonapatha for 21 days reduced serum glucose, triglyceride, and cholesterol levels in the glibenclamide-induced diabetic rats [94].

11. Antiobesic Effect

Obesity is one of the major health problems in humans and 13% of the adult world population is clinically obese. Obesity is associated with cardiovascular diseases, type II diabetes and certain cancers and Sonapatha has shown promise to reduce obesity preclinically. The 3T3-L1 adipocytes treated with hexanes, dichloromethane, ethyl acetate and methanol extracts of Sonapatha bark inhibited the lipid accumulation and lipase activity and the ethyl acetate extract was most effective [95]. Similarly, 3T3-L1 adipocytes exposed to 50, 100, 150 or 200 µg/mL of 95% Sonapatha ethanol fruit extract for 2 and 10 days suppressed the accumulation of lipids and lipase activity in 3T3-L1 adipocytes concentration-dependently. Sonapatha fruit extract also reduced lipids, lipid esters, nucleic acids, glycogen and carbohydrates in 3T3-L1 adipocytes [96]. The treatment of 3T3-L1 preadipocytes with 50, 100, 150 or 200 µg/mL fruit extract of Sonapatha inhibited lipid accumulation and the greatest effect was observed for 200 µg/mL. The study of mRNA expression showed that 200 µg/mL fruit extract suppressed the expression of fatty acid synthetase (FAS), sterol regulatory element-binding proteins 1c (SREBP-1c), proliferator-activated receptor-γ2 (PPARγ2), glucose transporter (GLUT4), and leptin in adipocytes indicating its potential as an antiobesity agent [97].

12. Anticancer Effect

The aqueous and methanol extracts of Sonapatha stem bark induced apoptosis in MDA-MB-435S (human breast carcinoma), Hep3B (human hepatic carcinoma), and PC-3 (human prostate cancer) cells [98]. The exposure of HeLa cells to 50, 100, 200, 250 and 500 petroleum ether, dichlromethane and methanol extracts of Sonapatha stem bark caused a concentration-dependent rise in the cytotoxic effect with an IC_{50} of 112.3±4.4, 171.7 ± 7.4 and 315.7 ± 6.5 µg/ml for petroleum ether, dichlromethane and methanol extracts, respectively. The petroleum ether extract was most cytotoxic and induced apoptosis indicated by membrane blebbing, nuclear fragmentation and apoptotic bodies and DNA fragmentation [62]. The petroleum and chloroform stem bark extract of Sonapatha has been reported to exert dose-dependent cytotoxicity in MDA-MB-231 and MCF-7 breast cancer cells by XTT assay and also induced apoptosis indicated by DNA fragmentation measured by ELISA [99]. The Sonapatha leaves extracted in methanol have shown the cytotoxic effect on HeLa cells with an IC_{50} of 3.87 µg/ml, whereas it did not exert any cytotoxicity on normal Vero and MDCK cells. The methanol leaf extract of Sonapatha induced apoptosis, which was characterized by nuclear fragmentation, condensation, and apoptotic bodies. The apoptosis induction by methanol extract was further characterized by FITC-Annexin V and propidium iodide assay by flow cytometry analysis. The flow cytometric evaluation has revealed the collection of cells in the G_1/S phase of the cell cycle by increasing p53 expression [100]. The cytotoxic effects of ethanol extract of wild Sonapatha and twigs cultured in vitro have triggered dose-dependent cytotoxicity in SiHa and HepG2 cells with IC_{50} of 440 and 480 µg mL-1, respectively for wild samples. However, the cytotoxicity was lower in the case of in vitro samples that exhibited the IC_{50} of 530 and 550 µg ml^{-1} for SiHa and HepG2 cells, respectively [101]. The root bark of Sonapatha extracted in chloroform, ethyl acetate and n-butanol showed lethality in the brine shrimp assay and it was also cytotoxic to MCF-7 cells [102]. The leaf, bark, pod, and seeds of Sonapatha extracted in ethanol showed a concentration-dependent increase in cytotoxicity by sulforhodamine B and clonogenic assays with the IC_{50} of 161.2±8.63, 286.73±33.01, 149.03±8.81, and 107.06±5.66 µg/mL for leaf, bark, pod, and seed extracts, respectively. The seed extract was most cytotoxic as indicated by colony-forming assay [103]. The leaves and fruit of Sonapatha extracted in ethanol were cytotoxic to MCF-7 cells in sulforhodamine B and clonogenic assays having an IC_{50} of 57.02 ± 2.85 µg/mL and 131.3 ± 19.2 µg/mL, respectively. The leaf extract also inhibited cell migration, activated caspase 3, and triggered apoptosis and suppressed the expression of MMP 9, ICAMP1, and Rac1 genes in MCF-7 cells. RhoA was significantly elevated by both leaf and fruit extracts in MCF-7 cells [104]. The methanol extract of Sonapatha leaves triggered cytotoxicity in a concentration-dependent manner with an IC_{50} of 6.25±1.06 µg/mL. The cytotoxic effect of Sonapatha seems to be mediated by the downmodulation of HPV18 oncoproteins E6 and E7, followed by the activation of caspase-8 and caspase-3 and higher mRNA expressions of p53, pRb, Fas, and FasL in HeLa cells. The Sonapatha methanol leaf extract increased IL-12 and reduced the IL-6 production in HeLa cells [105].

13. Wound Healing Effect

The root bark of Sonapatha extracted in methanol has been reported to heal partial burn wounds in mice receiving the topical application of 1 and 2.5% extract containing ointment. This was evident by higher wound contraction and reduced wound healing time. The histological evaluation revealed a time-dependent progression in the formation of dermis and reepithelialization. The methanol extract of Sonapatha also increased collagen synthesis and 2.5% extract was superior to 1% [106]. Topical application of 5, 10, 20, and 30 % ethanol stem bark extract of Sonapatha increased wound contraction and reduced the mean wound healing time in a dose-dependent manner of the full thickness excision wounds of mice. The 10% extract was most effective as it produced the highest wound contraction and reduced healing time maximally.

The biochemical analysis of collagen and DNA syntheses showed a dose-dependent rise, accompanied by a decline in the LOO. The Western blot analysis showed that infliction of excision wound upregulated NF-κB and COX-2, whereas topical application of Sonapatha ethanol extract reduced their expression [14].

14. Effect against COVID-19 Infection

Coronavirus disease 2019 (COVID-19) is an infectious disease caused by coronavirus-2 (SARS-CoV-2). Covid-19 became a pandemic at the beginning of 2020 and since then several deaths have occurred worldwide. Covid-19 infection is characterized by a severe life-threatening acute respiratory syndrome caused by hyperinflammatory response, vascular damage, microangiopathy, angiogenesis and widespread thrombosis. Currently, no specific treatment is available against COVID19 infection [107]. The COVID-19 entry into the primary host-cell is mediated by specific binding of coronavirus spike proteins (s) to the angiotensin-converting enzyme II (ACE2) receptors of human organs. Therefore, blocking of ACE2 can reduce COVID-19 entry into the cell. The molecular docking and the surface plasmon resonance studies have shown that oroxylin A present in Sonapatha can suppress the entry of the SARS-CoV-2-spiked pseudotyped virus into ACE2 cells, as it binds well to the ACE2 (blocking its availability for COVID-19) receptors as shown by surface plasmon resonance and cell membrane chromatography [108]. The 200 mg/kg baicalein another constituent of Sonapatha has been found to inhibit the replication of the COVID-19 virus and loss of body weight and reduce lung damage in hACE2 transgenic mice infected with SARS-CoV-2 and it also reduced SARS-CoV-2-induced injury in cultured Vero cells [109]. Baicalein inhibited the replication of SARS-CoV-2 in vitro with an IC_{50} of 10 μM in Vero E6 cells by reducing oxygen consumption rate, oxidative phosphorylation and mitochondrial membrane potential [110]. Molecular docking studies against the SARS-CoV-2 virus replication enzyme main protease (Mpro) revealed that four (baicalein-7-O-diglucoside, chrysin-7-O-glucuronide, oroxindin and scutellarein) of the eighteen constituents of Sonapatha had the potential to inhibit the activity of this enzyme and restrain COVID-19 infection [111].

References

1. Kalaivani, T.; Mathew, L. Phytochemistry and free radical scavenging activities of Oroxylum indicum. Environ. We Int. J. Sci. Technol. 2009, 4, 45–52.
2. Mishra, S.L.; Sinhamahapatra, P.K.; Nayak, A.; Das, R.; Sannigrahi, S. In vitro antioxidant potential of different parts of Oroxylum indicum: A comparative study. Indian J. Pharm. Sci. 2010, 72, 267–269.
3. Tenpe, C.; Upaganlawar, A.; Burle, S.; Yeole, P. In vitro antioxidant and preliminary hepatoprotective activity of Oroxylum indicum Vent leaf extracts. Pharmacologyonline 2009, 1, 35–43.
4. Gupta, R.C.; Sharma, V.; Sharma, N.; Kumar, N.; Singh, B. In vitro antioxidant activity from leaves of Oroxylum indicum (L.) Vent.—A North Indian highly threatened and vulnerable medicinal plant. J. Pharm. Res. 2008, 1, 65–72.
5. Kumar, V.; Chaurasia, A.K.; Naglot, A.; Gopalakrishnan, R.; Gogoi, B.J.; Singh, L.; Srivastava, R.B.; Deka, D.C. Antioxidant and antimicrobial activities of stem bark extracts of Oroxylum indicum Vent. (Bignoniaceae)—A medicinal plant of northeastern India. South Asian J. Exp. Biol. 2011, 1, 152–157.
6. Moirangthem, D.S.; Talukdar, N.C.; Bora, U.; Kasoju, N.; Das, R.K. Differential effects of Oroxylum indicum bark extracts: Antioxidant, antimicrobial, cytotoxic and apoptotic study. Cytotechnology 2013, 65, 83–95.
7. Lalrinzuali, K.; Vabeiryureilai, M.; Jagetia, G.C.; Lalawmpuii, P.C. Free radical scavenging and antioxidant potential of different extracts of Oroxylum indicum in vitro. Adv. Biomed. Pharma 2015, 2, 120–130.
8. Sithisarn, P.; Nantateerapong, P.; Rojsanga, P.; Sithisarn, P. Screening for antibacterial and antioxidant activities and phytochemical analysis of Oroxylum indicum fruit extracts. Molecules 2016, 21, 446.
9. Rasadah, M.A.; Houghton, P.J.; Raman, A.; Hoult, J.R.S. Antimicrobial and antiinflammatory activities of extracts and constituents of Oroxylum indicum (L.) Vent. Phytomedicine 1998, 5, 375–381.
10. Upaganlawar, A.; CR, T.; Yeole, P. Antiinflammatory activity of aqueous extract of Oroxylum indicum Vent. leaves extract-preliminary study. Pharmacol. Online 2009, 1, 22–26.
11. Doshi, K.; Ilanchezhian, R.; Acharya, R.; Patel, B.R.; Ravishankar, B. Anti-inflammatory activity of root bark and stem bark of Shyonaka. J. Ayurveda Integr. Med. 2012, 3, 194–197.
12. Joshi, S.V.; Vyas, B.A.; Shah, P.D.; Shah, D.R.; Shah, S.A.; Gandhi, T.R. Protective effect of aqueous extract of Oroxylum indicum Linn. (root bark) against DNBS-induced colitis in rats. Indian J. Pharmacol. 2011, 43, 656–661.

13. Asaduzzaman, M.; Nasrin, N.; Muhit, A.; Raihan, S.; Apu, A.; Akbar, A. Antidiarrheal, analgesic and cytotoxic activities of crude extract of Oroxylum indicum (L.) stem bark. J. Pharm. Res. 2011, 4, 4296–4298.
14. Hu, T.; Liu, S.; Zhao, L.; Qin, K. Preparation of Oroxylum indicum extracts and their anti-bacterial and anti-inflammatory activities. China Anim. Husb. Vet. Med. 2010, 37, 225–228.
15. Lalrinzuali, K.; Vabeiryureilai, M.; Jagetia, G.C. Investigation of the anti-inflammatory and analgesic activities of ethanol extract of stem bark of sonapatha Oroxylum indicum in vivo. Int. J. Inflam. 2016, 2016, 8247014.
16. Laloo, D.; Gogoi, B.; Lyngdoh, W.; Zaman, K.; Sharma, H. Antioxidant, analgesic and anti-inflammatory activities of bark of Oroxylum indicum Vent: An endemic medicinal plant of Northeast India. Asian J. Chem. 2016, 28, 2272–2276.
17. Begum, M.M.; Islam, A.; Begum, R.; Uddin, M.S.; Rahman, M.S.; Alam, S.; Akter, W.; Das, M.; Rahman, M.S.; Imon, A.H.M.R. Ethnopharmacological inspections of organic extract of Oroxylum indicum in rat models: A promising natural gift. Evid. Based. Complement. Alternat. Med. 2019, 2019, 1562038.
18. Bergeron, C.; Hamid, Q. Relationship between asthma and rhinitis: Epidemiologic, pathophysiologic, and therapeutic aspects. Allergy Asthma Clin. Immunol. 2005, 1, 81–87.
19. Lee, A.Y.; Kang, S.; Park, S.J.; Huang, J.; Im, D.S. Anti-allergic effect of oroxylin a from Oroxylum indicum using in vivo and in vitro experiments. Biomol. Ther. 2016, 24, 283–290.
20. Rasadah, M.A.; Houghton, P.J.; Hoo, T.S. Antifungal activity of some Bignoniaceae found in Malaysia. Phyther. Res. 1998, 12, 331–334.
21. Radhika, L.G.; Meena, C.V.; Peter, S.; Rajesh, K.S.; Rosamma, M.P. Phytochemical and antimicrobial study of Oroxylum indicum. Anc. Sci. Life 2011, 30, 114–120.
22. Islam, K.; Eti, Z.; Chowdhury, J.A. Phytochemical and antimicrobial analysis on the extract of Oroxylum indicum Linn. stem-bark. Iran. J. Pharmacol. Ther. 2010, 9, 25–28.
23. Samatha, T.; Sampath, A.; Sujatha, K.; Rama Swamy, N. Antibacterial activity of stem bark extracts of Oroxylum indicum an endangered ethnomedicinal forest tree. IOSR J. Pharm. 2011, 7, 24–28.
24. SatyaEswari, J.; Dhagat, S.; Naik, S.; Dibya, S. Oroxylum indicum leaf extracts for screening of antimicrobial properties and phytochemicals. Pharm. Bioprocess. 2018, 6, 7–14.
25. Das, S.; Choudhury, M.D. Antimicrobial activity of stem bark extracts from the plant Oroxylum indicum Vent. Assam Univ. J. Sci. Technol. 2010, 5, 95–99.
26. Chumkaew, P.; Srisawat, T. A new flavone from Oroxylum indicum and its antibacterial activity. Chem. Nat. Compd. 2021, 57, 274–276.
27. Deori, K.; Yadav, A.K. Anthelmintic effects of Oroxylum indicum stem bark extract on juvenile and adult stages of Hymenolepis diminuta (Cestoda), an in vitro and in vivo study. Parasitol. Res. 2016, 115, 1275–1285.
28. Islam, M.; Rahman, M.M.; Hasan, M.; Rahaman, M.; Khan, M.R.H.; Al-Faysal, A. Evaluation of anthelmintic activity of crude extracts and different fractions of stem bark and fruits of Oroxylum indicum. World J. Pharm. Res. 2016, 5, 287–294.
29. Tripathy, B.; Panda, S.; Sahoo, S.; Mishra, S.; Nayak, L. Phytochemical analysis and hepatoprotective effect of stem bark of Oroxylum indicum (L) Vent. on carbon tetrachloride induced hepatotoxicity in rat. Int. J. Pharm. Biol. Arch. 2011, 2, 1714–1717.
30. Sastry, A.; Sastry, V.; Mallikarjun, P.; Srinivas, K. Chemical and pharmacological evaluation of aqueous extract of root bark of “Oroxylum indicum” Vent. Int. J. Pharm. Technol. 2011, 3, 1796–1806.
31. Das, S.; Duttachoudhury, M.; Mandal, S.C.; Talukdar, A. Traditional knowledge of ethnomedicinal hepatoprotective plants used by certain ethnic communities of Tripura state. Indian J. Fundam. Appl. Life Sci. 2012, 2, 84–97.
32. Mishra, S.; Sahoo, S. In vitro and in vivo antihepatotoxic activity of Oroxylum indicum against carbon-tetrachloride induced hepatic damage. Int. J. Pharm. Sci. Res. 2013, 4, 3202–3207.
33. Bharali, M.K.; Konya, H.; Bahadur, C.L. Protective effect of Oroxylum indicum on acetaminophen induced liver injury in rat. Int. Curr. Pharm. J. 2014, 3, 223–227.
34. More, A.; Shah, T.; Parab, P.; Apte, K. Oroxylum indicum (Linn.) whole stem extract regulates expression of TNFα, IL6, NFkB, P38 MAPK and oxidative status in antitubercular therapy induced hepatotoxicity in Wistar rats. Matters 2017, 3, e201704000014.
35. Mohapatra, S.S.; Roy, R.; Mohan, P.; Upadhyaya, T.; Sarma, J. Phytochemical analysis and hepatoprotective effect of hydroethanolic extract of stem bark of Oroxylum indicum. Int. J. Curr. Microbiol. Appl. Sci. 2018, 7, 1000–1006.

36. Sun, W.; Liu, P.; Yang, B.; Wang, M.; Wang, T.; Sun, W.; Wang, X.; Zheng, W.; Song, X.; Li, J. A network pharmacology approach: Inhibition of the NF-κB signaling pathway contributes to the NASH preventative effect of an Oroxylum indicum seed extract in oleic acid-stimulated HepG2 cells and high-fat diet-fed rats. Phytomedicine 2021.