Asian Journal of Chemistry; Vol. 34, No. 3 (2022), 459-472

ASIAN JOURNAL OF CHEMISTRY

https://doi.org/10.14233/ajchem.2022.23479

REVIEW

Oroxylum indicum Vent.: A Review on its Phytochemical and Pharmacological Profile

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Received: 14 August 2021; *Accepted*: 30 September 2021; *Published online*: 14 February 2022; AJC-20675

Oroxylum indicum Vent. is an important herbal medicinal plant of South-East Asian countries. The plant parts are used in several traditional medicines to cure various diseases. It has been known to possess antimicrobial, anti-inflammatory, anticancerous, antiulcer and hepato-protective activities. A wide range of bioactive compounds (like aloe-emodin, chrysin, baicalein, oroxylin A, oroxin A-D, hispiludin and ursolic acid) have been isolated from it, of which flavonoids constitute major secondary metabolites. The presented review summarizes the works undertaken till date, concerning the ethnobotany, phytochemistry and pharmacological study of the plant.

Keywords: *Oroxylum indicum*, Flavonoids, Chrysin, Oroxin A, Antioxidant, Antidiabetic.

INTRODUCTION

Oroxylum indicum Vent. (Bignoniaceae) (Fig. 1) is a medium sized tree [1] and has been extensively used for centuries in many Asian countries [2]. The generic name Oroxylum is derived from two Greek words oros and xylon meaning 'mountain' and 'wood' respectively, while the specific epithet indicum means 'of India' [3]. It is also known by other names such as 'Indian trumpet tree', 'broken bones tree' and 'tree of damokles' in English. While the name 'midnight horror tree' is due to its pods giving noise which at night sounds horrible creating fear [4]. In India, various vernacular names such as shyonaka (Sanskrit), shallaka (Hindi), alangi (Kannada), achi (Tamil), napakban (Karbi), davamadak (Konkani), tayitu (Marathi), toguna (Assamese), sona (Bengali) and shamba (Manipuri) are known. While it is known by yuhudie (Chinese), abang-abang (Indonesia), pokok beka (Malaysia), totola (Nepal), mak lin mai (Laos), pinka-pinkahan (Philippines), kyaung shar (Myanmar), lin fa (Thailand), sonaka (Tibet), nuc nac (Vietnam), paksam (Bhutan), thotila (Sri Lanka). It is widely distributed in the Indian subcontinent, in the Himalayan foothills with a part extending to Bhutan and China and the Malaysia ecozone [5]. In India, it is found in eastern, western Ghats and North East region up to an altitude of 1200 m and found mainly in ravine and moist places in forests [6]. The fully matured plant attained between 7.5 and 12 m in height, with numerous corky lenticels. It has two to three times pinnately compounded leaves and the shape of the leaflets is ovate or elliptic and rounded or cordate at the base. The flowers have purplish to reddish purple outside and pinkish within, giving way to flattened woody seed capsules up to 1 m long, each containing numerous flattened winged seeds. The flowers are born in rainy season and fruit appears from December to March [7].

In India, *O. indicum* was distributed throughout the great parts of India but now it is listed amongst endangered species in many areas in the country [8]. Herein, we are presenting the review of *O. indicum* in continuation of our interest in useful medicinal plants found in North-Eastern India [9-11] and it was conducted based on published articles on PubMed, Medline and Web of Science databases. In this study, the search strategy identified 108 references.

Ethnomedicinal uses: *O. indicum* is an important herbal medicine in many Asian countries as its leaves, fruits, stem and root barks are used in folk medicine as a cure of various diseases. It is also recognized as ethno-veterinary plant for treatment of snake bite in camels [12]. The plant is used as

Fig. 1. *Oroxylum indicum* plant bearing fruits and flowers

one of the important ingredients in most commonly used Ayurvedic preparation, named as Dashmularisht [13]. It is also used in other Ayurvedic formulation such as Amartarista, Dantyadyarista, Narayana Taila, Dhanawantara Ghrita, Brahma Rasayana, Chyavanaprasa Awalwha, *etc*. [14]. A detailed view of the ethno-medicinal uses of different parts of this plant is summarized in Table-1.

Phytochemistry: The phytochemical studies of the various parts of *O. indicum* revealed the presence of flavonoids, napthalenoids, cyclohexylethanoids, steroids and stilbenoids as a major class of compounds. The elemental analysis of stem, root and leaves indicates the presence of Na, Ca, Cu, Fe, Zn and Mn which are all below WHO acceptable levels and may not amount to a health hazard for consumers [27]. The study on various parts of *O. indicum* indicated the maximum present of flavonoids and phenolics contents in methanolic extract of the plant. The results showed high phenolic (12.4 mg/g) content from *in vitro* root of the plant followed by (11.1 mg/g) from *in vivo* leaves while there is no significant difference between *in vitro* developed root (1.0 mg/g) and *in vivo* root (1.0 mg/g) for flavonoids content [28]. The leaves are rich in essential oil [29]. Thirty-nine components were identified, of which tumerone (19.4%), a sesquiterpene ketone, was the major constituent in the oil followed by methyl hexadecanoate (6.2%), laurenan-2-one (5.6%) and isopropyl butanoate (5.6%). The nutritional qualities of *Oroxylum indicum* pod flour was investigated revealing the presence of high amounts of crude protein, ash, crude fiber, carbohydrates (8.5, 4.1, 18.9 and 67.5 g/100 g, respectively) and total dietary fibers (42.5%). The pod flour contained cysteine and glutamic acid (15.3 and 10.6 g/100 g crude protein, respectively) as predominant amino acids, with appreciable amounts of total unsaturated fatty acids [30]. The various chemical compounds isolated so far are listed in Table-2.

Flavonoids: An impressive diversity of free flavonoids has been isolated from *O. indicum* (more than eighty compounds). Some important flavonoids are shown in Fig. 2. These include thirty seven flavones (**1**-**37**), two flavanones (**37**-**38**) and one biflavonoid (**39**). The most abundant ones are baicalein [4], chrysin [6] and oroxylin A [28]. Forty-three flavonoid glycosides have been reported from *O. indicum*. They can be classified into O-glucosides (**40**-**66**), O-glucuronides (**67**-**78**) and C-glycosides (**79**-**82**). For most of the O-glucosides, the glucosyl residues are substituted at 7-OH or 3-OH. Tetuin [53] and 5-hydroxyl-7-methoxy-2-(2-methoxy-6-(3,4,5-trihydroxy-6-(hydroxymethyl)tetrahydro-2*H*-pyran-2-yloxy)phenyl)-4*H*-chromen-4-one [45] are exceptions. Up to now, four C-glycosides have been isolated which are linked through positions 6 and 8. Most of them are glycosides of chrysin and six isoflavones (**83**-**88**) have been isolated so far.

Other important compounds: *O. indicum* contains a rich source of naphthalenoids including catalponol (**99**) and dehydro-iso-α-lapachone (**103**). Nineteen (**89**-**107**) naphthalenoids have been isolated from heartwood, root and stem barks. Nine cyclohexylethanoids (**108**-**116**) and four phenylethanoids (**117**-**120**) and five stilbenoids (**121**-**125**) were also successfully isolated

TABLE-1
TRADITIONAL USES OF VARIOUS PARTS OF *Oroxylum indicum*

Country	Ethnomedicinal use	Ref.
Bangladesh	Leaves are used for constipation, helminthiasis and appetite stimulant	[15]
Bhutan	Fruit and its ash are used to heal deep cuts and wounds	[16]
Cambodia	The bark is used to treat burn, cough, fever and malaria. While root for leucorrhea and fruits for post-partum treatments are also used.	[17]
China	The seed is used for reducing hyperactivity, relieving sore throat, smoothing the liver and treating stomach ailments	[18]
Laos	The bark is used to treat fever and stem/root for malaria	[19]
India	The decoction of bark is used to treat gastric problem. Bark, pod, flower are used for jaundice, headache, womb ailment and hypertension	[20]
Indonesia	Leaves are used to treat kidney disease	[21]
Malaysia	Bark is used for treating malaria and hypertension	[22]
Myanmar	Bark of trunk and root used as an astringent and a tonic in dysentery, diarrhea and rheumatism. The juice of leaf is taken as a remedy for opium toxicity	[23]
Nepal	Seed is eaten for typhoid, fever. Ash of bark is applied on infective wounds.	[24]
Sri Lanka	Leaves are used for snakebite treatment	[25]
Thailand	The leaf is used for treating inflammatory symptoms in urticaria	[26]

TABLE-2
LIST OF COMPOUNDS ISOLATED FROM DIFFERENT PARTS OF *Oroxylum indicum*

Entry	Compound isolated	Sources	Ref.
Flavonoids			
1	Acacetin (5,7-dihydroxyflavone) (**1**)	SD	[31]
2	Acetyl chrysin (5-hydroxy-7-acetoxyflavone) (**2**)	BS	[32]
3	Apigenin (5,7,4'-trihydroxyflavone) (**3**) and baicalein (5,6,7-trihydroxyflavone) (**4**)	SB	[33]
4	Baicalein-7-O-caffeate (**5**)	SB	[34]
5	Chrysin (5,7-dihydroxyflavone) (**6**)	SB	[33]
6	5,7-Dihydroxyflavone (**7**), 5,4'-dihydroxy-7-methoxyflavone (**8**), 5,7-dihydroxy-6-methoxyflavone (**9**), 5,6,7,4'-tetrahydroxyflavone (**10**), 5,7,4'-trihydroxy-6-methoxyflavone (**11**), 5,7,4'-trihydroxy-3'-methoxyflavone (**12**) and 5,7,4'-trihydroxyflavone (**13**)	NS	[35]
7	2,5-Dihydroxy-6,7-dimethoxyflavone (**14**) and 3,7,3',5'-tetramethoxy-4'-hydroxyflavone (**15**)	RT	[36]
8	6-Hydroxyflavone (**16**)	RT	[37]
9	5-Hydroxy-4',7-dimethoxyflavone (**17**)	SB	[38]
10	5,4'-Dihydroxy-3,6,7-trimethoxyflavone (**18**) and diosmetin (5,7,3'-trihydroxy-4'-methoxyflavone) (**19**)	SD	[39]
11	Kaempferol (3,4',5,7-tetrahydroxyflavone) (**20**)	SB	[40]
12	Hispidulin (4', 5, 7-trihydroxy-6-methoxyflavone) (**21**)	SB	[33]
13	Isorhamnetin (3-methylquercetin) (**22**)	SD	[31]
14	6-Methoxyluteolin (6-methoxy 5,7,3',4'-tetrahydroxy-flavone) (**23**) and 6-hydroxyluteolin(5,6,7,3',4'-pentahydroxyflavone) (**24**)	SB	[34]
15	Methoxychrysin (7-*O*-methylchrysin) (**25**)	SB	[41]
16	Mosloflavone (5-hydroxy-6,7-dimethoxyflavone) (**26**)	SD	[42]
17	Neglectein (5,7-dihydroxy-6-methoxy-2-phenylchroman-4-one) (**27**)	BS	[32]
18	Norwogonin (5,7,8-trihydroxyflavone) (**28**)	SD	[31]
19	Oroxylin-A (6-methoxy baicalein) (5,7-dihydroxy-6-methoxyflavone) (**29**)	SB	[33]
20	Pectolinarigenin (5,7-dihydroxy-6-methoxyflavone) (**30**)	SB	[43]
21	Pinobanksin (3,5,7-trihydroxyflavone) (**31**) and pinocembrin (5,7-dihydroxyflavanone) (**32**)	SD	[44]
22	Pinostrobin (pinocembrin-7-methylether) (**33**)	SB	[45]
23	Quercetin (3',4',3,5,7-pentahydroxyflavone) (**34**)	SD	[46]
24	Scutellarein (5,6,7,4'-tetrahydroxyflavone) (**35**)	SD	[31]
25	Scutellarein 4'-methyl ether (5,6,7-trihydroxy-4'-methoxy-flavone) (**36**)	SB	[43]
26	Dihydro-baicalein (5,6,7-Trihydroxyflavanone) (**37**)	LF	[47]
27	Dihydro-oroxylin A [(2*S*)-5,7-dihydroxy-6-methoxyflavanone)] (**38**)	SB	[38]
28	8,8''-Bibaicalein (**39**)	SB	[34]
Flavonoid glycosides			
29	Baicalein 7-O-β-D-glucuronopyranosyl-(1→3)[β-D-glucopyranosyl-(1→6)]-β-D-glucopyranoside (**40**) and Chrysin-7-O-gentiobioside (**41**)	SD	[44]
30	Chrysin-7-O-β-D-glucopyranosyl-(1→6)- β-D-glucopyranoside (**42**)	SD	[48]
31	Chrysin-7-O-methyl glycoside (**43**)	SB	[41]
32	Chrysin-diglucoside (**44**)	LF	[49]
33	5-Hydroxyl-7-methoxy-2-(2-methoxy-6-(3,4,5-trihydroxy-6-(hydroxymethyl)tetrahydro-2*H*-pyran-2-yoloxy)phenyl)-4*H*-chromen-4-one (**45**)	SB	[38]
34	Oroxin-A (baicalein-7-O-glucoside) (**46**)	SD	[31]
35	Oroxin-B (baicalein-7-O-β-gentiobioside) (Baicalein-7-O-diglucoside) (**47**)	SD	[46]
36	Oroxin-C (baicalein 7-*O*-β-D-glucopyranosyl-(1→6)-β-D-glucopyranosyl-(1→6)-β-D-glucopyranoside) (**48**) and Oroxin-D (scutellarein 4'-methylether 7-*O*-β-D-glucopyranosyl-(1→6)-β-D-glucopyranoside (**49**)	SD	[48]
37	Oroxylin-A-7-O-glucoside (**50**) and 5,6,7-trimethoxyflavone-8-O-β-D-glucopyranoside (**51**)	SB	[50]
38	(2*S*)-Dihydrobaicalein-7-O-(6''-benzoylglucopyranoside) (**52**)	SB	[43]
39	Tetuin (baicalein-6-glucoside) (**53**)	RT	[51]
40	Pinocembroside (pinocembrin-7-O-β-D-glucoside) (**54**) and scutellarein-7-rutinoside (**55**)	SD	[42]
41	Scutellarein-7-O-β-D-glucopyranosyl-(1→6)-β-D-glucopyranoside) (**56**) and scutellarein-7-O-glucopyranoside (**57**)	SD	[44]
42	Isoquercetin (quercetin-3-O-β-D-galactopyranoside) (**58**), isorhamnetin (3-methylquercetin) (**59**) and kaempferol-7-O-β-D-glucopyranoside (**60**)	SD	[31]
43	Quercetin-7-O-β-D-glucopyranoside (**61**) and quercetin-3-O-α-L-arabinoside (**62**)	SD	[48]
44	Quercetin-7-O-β-D-glucopyranoside (**63**)	SD	[52]
45	Quercetin-3-O-ara-binopyranoside (**64**)	SD	[46]
46	Quercetin-3-O-rutinoside (**65**) and quercitroside (quercetin-3-rhamnoside) (**66**)	SD	[39]
47	Baicalein-6-glucuronide (**67**)	SB	[53]
48	Baicalein-6-methoxy-7-glucuronide (**68**)	SB	[50]
49	Baicalin (baicalein-7-O-β-D-glucuronide/baicalein-7-O-glucuronide) (**69**)	SB	[33]
50	Chrysin-7-O-glucuronide (aequinetin) (**70**), chrysin-7-O-β-D-glucuronide (**71**) and chrysin-7-O- β-D-glucuronide ethyl ester (**72**)	SD	[31]

51	Dihydrooroxylin-A-7-O-methylglucuronide (**73**)	SB	[38]
52	Oroxyloside (oroxylin-A-7-O-glucuronide) (**74**)	HW	[54]
53	Oroxyloside methyl ester (oroxylin-A-glucuronide methyl ester) (**75**)	SB	[41]
54	Oroxindin-A (wogonin-7-O-β-D-glucuronide) (**76**)	SD	[55]
55	Oroxylin A-7-O- β-D-glucuronide butyl ester (**77**)	SB	[50]
56	Scutellarin (scutellarein-7-glucuronide) (**78**)	SD	[42]
57	Chrysin-8-*C*-β-D-glucopyranoside (**79**)	SD	[31]
58	Chrysin-6-C-β-D-glucopyranosyl-8-C-α-L-arabinopyranoside (**80**) and chrysin-6-C-β-D-glucopyranosyl-8-O-β-D-glucuronopyranoside (**81**)	SD	[44]
59	Isoorientin (luteolin-6-C-glucoside) (**82**)	SD	[39]
Isoflavones			
60	Biochanin-A (5,7-dihydroxyisoflavone) (**83**)	RT	[56]
61	4',5-Dihydroxy-7-methoxyisoflavone (prunetin) (**84**)	HW	[57]
62	Undecanyl oroxylopterocarpan (**85**), heptyl oroxylopterocarpan (**86**), hexyl oroxylopterocarpan (**87**) and methyl oroxylopterocarpan (**88**)	SB	[58]
Naphthalenoids			
63	(3*R*,4*R*)-3, 4-Dihydro-4-hydroxy-3-(3-hydroxymethyl-(2*Z*)-butenyl)-1(2*H*)-naphthalenone (**89**), (3R,4R)-3,4-dihydro-4-hydroxy-3(3-methyl-2-butenyl)-1(2*H*)-naphthalenone (**90**), (2*S*,3*S*,4*R*)-3,4-dihydro-3,4-dihydroxy-2-(3-methyl-2-butenyl)-1(2*H*)-naphthalenone (**91**), (2*R*,3*aS*,9*S*,9*aR*)-9-hydroxy-2-(1-methylethenyl)-2,3,9, 9*a*-tetrahydro-3*aH*naphtho-[2,3-*b*]furan-4-one (**92**), (2*R**,3*aR**,5*S**,9*bR**)-2,3,3*a*,4,5,9*b*-hexahydro-2-(1-hydroxy-1-methylethyl)-5-naphtho[1,2-*b*]furanol (**93**), (2*R**,3*aR**,9*bR**)-2-(1-hydroxy-1-methylethyl)-2,3,3*a*,9*b*-tetrahydro-4*H*-naphtho[1,2-*b*]furan-5-one (**94**), [3*S*, 4*aR*, 10*b*R]-2,2-dimethyl-3-hydroxy-3,4,4*a*,10*b*-tetrahydro-5*H*-naphtho[1,2-*b*]-pyran-6-one (**95**), spiro[(1*aS*,2*R*,7*aS*)-2,3-dihydroxy-1*a*,2,7,7*a*-tetrahydronaphtho[2,3-*b*]oxirene-7,2'-naphtho[1,8-*de*]-1',3'-dioxin] (**96**), 2-acetyl-naphtho[2,3-*b*]furan-4,9-dione (**97**), 2-(Prop-1-en-2-yl)naphtha[2,3-*b*]furan-4,9-dione (**98**), catalponol (**99**), faramol (**100**) and 2-(1-hydroxymethylethyl)-4*H*,9*H*-naphtho[2,3-*b*]furan-4,9-dione (**101**)	RB	[59]
64	Lapachol (**102**)	RS	[60]
65	Dehydro-iso-α-lapachone (**103**)	SB	[38]
66	2-Methoxystypandrone (**104**)	NS	[35]
67	*N*-Phenyl-1-naphthylamine (**105**), naphthalene (**106**) and 2(1*H*)-naphthalenone, 4*a*,5,6,7,8,8*a*-hexahydro-4*a*-methyl (**107**)	RT	[37]
Cyclohexylethanoids			
68	Keto form of rengyoxide (**108**), (±)5,6-dihydrocornoside (**109**), (±) 6 α-hydroxydihydrocornoside (**110**), cornoside (**111**), dihydrorengyolone (**112**), 6α-methoxydihydrorengyolone (**113**), rengyol (**114**) and regyolone (**115**)	FT	[61]
69	Isorengyol (**116**)	SD	[46]
Phenylethanoids			
70	Salidroside (**117**), 2(3,4-dihydroxyphenyl)-ethylglucoside (**118**) and acteoside (**119**)	FT	[61]
71	Isoverbascoside (**120**)	HW	[54]
Stilbenoids			
72	(*E*)-Dihydropinosylvin-2-carboxyl-5-O-β-D-glucopyranoside (**121**), (*E*)-dihydropinosylvin-3-O- β-D-glucopyranoside (**122**), (*E*)-Pinosylvin-3-O-β-D-glucopyranoside (**123**), dihydropinosylvin (**124**) and pinosylvin (**125**)	SD	[62]
Terpenoids			
73	2α-Hydroxyllupeol (**126**)	SD	[44]
74	Lupeol (**127**) and lup-20(29)-ene-2*a*,3*b*-diol (**128**)	SD	[46]
75	2 α,3 β-Dihydroxyllupeol (**129**)	SD	[52]
76	Ursolic acid (**130**)	SD	[46]
77	Squalene (**131**)	RT	[37]
Steroids			
78	β-Sitosterol (**132**)	RT	[51]
79	β-Sitosterol-3-O-β-D-glucopyranoside (**133**)	SB	[43]
80	β-Sitosterol-3-O-glucoside (**134**) and stigmasterol-3-O-glucoside (**135**)	RT	[51]
81	Stigmast-7-en-3-ol (**136**)	SB	[45]
82	Stigmasterol (**137**)	SD	[52]
83	Daucosterol (**138**) and cholest-5-ene-3, 7-diol (**139**)	SD	[46]
Xanthones			
84	5'-Demethoxycadensin G (**140**), 1,7-dihydroxyxanthone (**141**), 1,3,6-trihydroxy-7-methoxy-2-(3,7-dimethyl-2,6-octadienyl)xanthone (**142**) and 3,7-dihydroxy-1-methoxyxanthone (**143**)	NS	[35]
Phenolics			
85	Ellagic acid (**144**)	RT	[56]
86	Gallic acid (**145**)	SD	[39]
87	*p*-Coumaric acid (**146**)	SB	[53]
88	Salicylic acid (**147**), *p*-hydroxybenzoic acid (**148**), protocatechuic acid (**149**), isovanillin (**150**) and β-hydroxypropiovanillon (**151**)	HW	[54]
89	Phenol (**152**), 5-methyl-2-(1-methylethyl) (**153**), isovanillic acid (**154**) and phenol, 2,4-*bis*(1,1-dimethylethyl) (**155**)	RT	[37]
90	4-Hydroxy-3-methoxybenzaldehyde (**156**) and 1-(4-hydroxyphenyl)propan-1-one (**157**)	NS	[35]

Alkaloids			
91	Echinulin (**158**)	SD	[44]
92	Tryptamine (**159**) and pseudopelletierine (**160**)	RT	[37]
93	Zarzissine (**161**)	SD	[63]
Fatty acids			
94	9,12-Octadecadienoic acid (linoleic acid) (**162**), ricinoleic acid (**163**), pentadecanoic acid (**164**), hexadecanoic acid (palmitic acid) (**165**) and tetradecanoic acid (myristic acid) (**166**)	RT	[37]
95	Caprylic acid (**167**), lauric acid (**168**), myristoleic acid (**169**) and palmitoleic acid (**170**)	SD	[64]
96	Stearic acid (**171**) and oleic acid (**172**)	SD	[65]
Esters			
97	Acetic acid, 2-(dimethylamino) ethyl ester (**173**), butanoic acid, butyl ester (**174**), 2-chloroethyl linoleate (**175**), diisooctyl phthalate (**176**), ethanedioic acid, dibutyl ester (**177**), L-(+)-ascorbic acid 2,6-dihexadecanoate (**178**), *bis*(2-ethylhexyl) phthalate (**179**), 1,1-dibutoxybutane (**180**), methyl (9*Z*,12*E*)-octadeca-9,12-dienoate (**181**), carbonic acid ethylhexadecyl ester (**182**), eicosyl trifluoroacetate (**183**), isopropyl palmitate (**184**), 2-ethylbutyric acid, eicosyl ester (**185**) and myristyl myristate (**186**)	RT	[37]
Hydrocarbons			
98	1-Dodecene (**187**), 1-tetradecene (**188**), 1-hexadecene (**189**), 1-octadecene (**190**), eicosane (**191**), squalan (**192**), heptadecane, 8-methyl (**193**), hexadecane (**194**), nonadecane (**195**), heneicosane (**196**), tetracosane (**197**), 2-methylhexacosane (**198**), hexacontane (**199**) and tetratetracontane (**200**)	RT	[37]
Others			
99	Adenosine (**201**)	SD	[63]
100	Uracil (**202**)	SB	[50]
101	Benzoic acid (**203**)	RT	[37]
102	Heraclenin (**204**)	NS	[35]
103	Aloe-emodin (**205**)	LF	[47]
104	Geniposide (**206**)	SD	[39]
105	2-Methyl-6-phenyl-4*H*-pyran-4-one (**207**) and dimethyl sulfone (**208**)	SD	[44]
106	Ficusal (**209**) and balanophonin (**210**)	HW	[54]
107	1-Eicosanol (**211**), *n*-nonadecanol-1 (**212**), *n*-tetracosanol-1 (**213**), 1-heptacosanol (**214**), phthalic acid (**215**), 2,4-dihydroxy-2,5-dimethyl-3(2*H*)-furan-3-one (**216**), 2,3-dihydro-5,6-dimethyl-1,4-dioxin (**217**), 2-furancarboxylic acid (**218**), 2,3-dihydro-3,5-dihydroxy-6-methyl-4*H*-pyran-4-one (**219**), pyrrolo[1,2-*a*]pyrazine-1,4-dione, hexahydro-3-(2-methylpropyl) (**220**), 5-hydroxymethylfurfural (**221**), 1,13-dibromotridecane (**222**), 7,9-di-*tert* butyl-1-oxaspiro[4.5]deca-6,9-diene-2,8-dione (**223**), 3,4-altrosan (**224**), *D*-ribose, 2-deoxy-*bis*(thioheptyl)-dithioacetal (**225**), silane, diethylheptyloxyoctadecyloxy (**226**), iron, tricarbonyl[*N*-(phenyl-2-pyridinylme] (**227**), *N*-(6-*tert*-butyl-5-oxo-1,2,4-triazin-4(5*H*)-yl)formamide (**228**), 2-ethylhexanal (**229**), 1,2,3-propanetriol, 1-acetate (**230**), 2,5-anhydro-1,6-dideoxyhexo-3,4-diulose (**231**) and 1-butoxy-1-isobutoxy-butane (**232**)	RT	[37]

LF = Leaves, RT = Root, RB = Root bark, SD = Seed, SB = Stem bark, HW = Heartwood, NS = Not specified.

from *O. indicum*. None of these compounds were isolated from leaves and stilbenoids were isolated from seed only. Six terpenoids (**126-131**), eight steroids (**132-139**) and four xanthones (**140-143**) were isolated from *O. indicum*, of which β-sitosterol (**132**) is the most common among steroids. Thirteen phenolic compounds (**145-157**) were also reported from *O. indicum* and only four alkaloids (**158-161**) are reported from it and out of eleven fatty acids (**162-172**) reported so far linoleic acid (**162**), palmitic acid (**165**) and myristic acid (**166**) are the main ones. The roots are also rich in fourteen esters (**173-186**) as well as hydrocarbons (**187-200**). Further, *O. indicum* also contain thirty three miscellaneous compounds (**201-232**) consisting of purine bases, lignans, anthraquinone, coumarin, iridoid glycoside, sugars, alcohols, glycols and other.

Pharmacological profile: In the literature, several traditional uses of *O. indicum* are described. However, a scientific validity and supporting evidence is a pre-requisite for commercial exploitation. In the preceding text, some of the recent reports pertaining towards the pharmacological potential of the plant extracts are being discussed. Table-3 provides an overview of some important works (last 5 years) on the pharmacological properties of plant extracts and the isolated compounds and their activities undertaken so far.

Antimicrobial activities: Nemkul & Shrestha [24] reported that stem bark, leaf and seed of *O. indicum* possess antimicrobial property against Gram-positive (*Staphylococcus aureus* and *Bacillus subtilis*) and Gram-negative (*Salmonella typhi*, *Klebsiella pneumoniae* and *Escherichia coli*) bacteria. Among the tested bacteria, the maximum zone of inhibition was observed in methanolic extract of *O. indicum* leaf against *E. coli* (23 mm) followed by hexane extract of leaf against *S. aureus* with 15 mm. The stem bark extract showed moderate antimicrobial property compare to leaf extract. However, seed extract did not show antimicrobial property to the test bacteria except *K. pneumonia* (8 mm). This confirmed the traditional uses of the plant in wound healing, diarrhoea and dysentery. The *O. indicum* extract also exhibited inhibitory zones (ZI) against yeast like *Candida albicans, Candida tropicalis, Cryptococcus marinus* and *Candida glabrata* ranging from 10.9-18.5 mm and restriction zones against mycelial like *Rizopus oryzae*, *Aspergillus flavus*, *Aspergillus niger Epidermophyton floccosum, Microsporum gypseum* and *Aspergillus brasiliensis* (14.2-24.2 mm) fungal strains [68]. The antiviral activities of *O. indicum* leave extracts on Chikungunya virus infection was examined [102]. Both methanol and aqueous extracts had similar cytotoxicity *in vero* cells. However, the

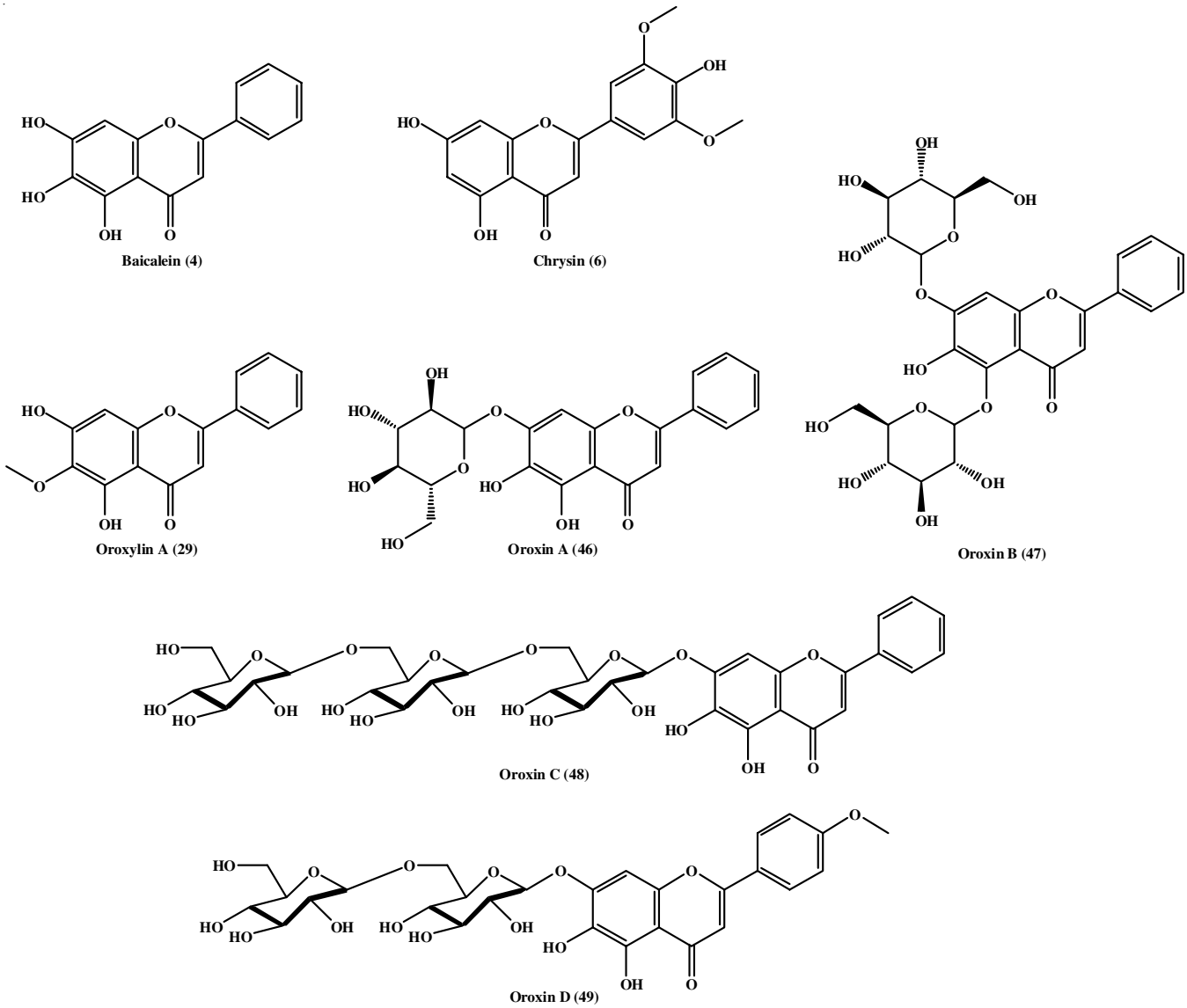

Fig. 2. Structure of some selected compounds isolated from *Oroxylum indicum* Vent.

virucidal effect of aqueous extract revealed a significant reduction on the viral titre ($p < 0.05$). Also, the prophylactic effect of aqueous extract was demonstrated when the pretreated cells exhibited a significant anti-CHIKV activity ($p < 0.05$). There is not much works on antiviral activity, further detailed studies are warranted on these aspects.

Antioxidant activities: Yossathera *et al*. [35] reported the isolation of 16 compounds of which 2 flavones, namely 5,6,7,4′-tetrahydroxyflavone (**10**) and 5,7,4′-trihydroxy-3′-methoxyflavone (**12**), exhibited strong and moderate antioxidant activities with IC_{50} values of 11.88 ± 0.06 and 33.45 ± 1.45 μM, respectively. They also studied the activities of different parts of *O. indicum* (leaves, stem, twig and root) extracted in acetone, dichloromethane, methanol and hexane. Of all the extracts, the acetone extract of the leaves and roots exhibited strongest antioxidative activity with IC_{50} values of 8.01 ± 0.29 and 9.81 ± 0.09 μg/mL, respectively. Further, the enzymes SOD, CAT, GSH and GPx which are responsible for detoxification mechanism in liver were found to be decreased in liver tissues due to the oxidative stress caused by 4-nitroquinoline 1-oxide (4-NQO) as reported [73]. According to them, the level of antioxidants was found to be increased with increasing concentration *i.e.* 50, 100 and 200 mg/kg body weight (b.w.) of *O. indicum* leaf extract given orally to albino Wistar rats for a month after 4-NQO administration. These studies confirm the strong antioxidant effect of *O. indicum*, thus *O. indicum* based formulations for antiageing and immune health support will be fruitful.

Anti-inflammatory activities: Wu *et al*. [48] isolated ten flavonoids from the seeds of *O. indicum* and were evaluated for their inhibition of (nitric oxide) NO production in murine macrophages cell line (RAW264.7). Two flavonoids namely chrysin (**6**) and chrysin-6-C-β-D-glucopyranosyl-8-C-α-L-arabinopyranoside (**80**) were reported to show moderate inhibitory effects on the production of NO with IC_{50} values of 18.63 ± 0.91 and 28.69 ± 0.43 μM, respectively, compared to BAY11-7082 as the positive control with IC_{50} value of 2.99 ± 0.46. Begum *et al*. [75] reported the anti-inflammatory activity of

TABLE-3
Oroxylum indicum EXTRACTS OR ISOLATED CHEMICAL COMPOUNDS WITH THEIR ACTIVITIES

S. No.	Extract/isolated compound(s)	Parts	Method(s)	Result	Ref.
Antimicrobial activities					
1	Hexane & methanol	SB, S & L	Diffusion technique	Inhibited the growth of *Salmonella typhi, Escherichia coli, Staphylococcus aureus, Bacillus subtilis* and *Klebsiella Pneumoniae* ranging from 7-23 mm zone of inhibition (ZI) at 0.1g/mL.	[23]
2	5,6,7-Trimethoxyflavone-8-O-*b*-D-glucopyr-anoside (**51**) and 6-methoxy-baicalein (**29**)	SB	Broth dilution	Inhibited the growth of *Staphylococcus aureus* with minimum inhibition concentration (MIC) ranging from 32–128 mg/mL.	[50]
3	5,7,4'-trihydroxy-6-metho-xyflavone (**12**) and 5'-demethoxycadensin G (**140**)	NS	Broth dilution	Inhibited the growth of *B. cereus* by **12** with MIC value of 16 mg/mL and MRSA SK1 by **140** with MIC value of 32 µg/mL.	[35]
4	Hexane, ethanol and aqueous	SB	Cup-plate method	Inhibited the growth of *E. coli* and *S. aureus,* ranging from ZI of 0.9-1.5 cm at 4 mg/mL.	[66]
5	Ethanol and aqueous	F	Diffusion method	Inhibited the growth of *Staphylococcus intermedius* and *Streptococcus suis* with ZI values of 10-15 mm at 1000 mg/mL.	[67]
6	Methanol:dichloromethane	WP	Diffusion & poisoned food methods	Inhibited the growth of *S. flexneri* (MIC=39.06 µg/mL). While for *S. enterica typhimurium*, *K. Pneumonia*, *P. aeruginosa, C. marinus*, *C. albicans* and *C. Albicans* (MIC = 78.12 µg/mL).	[68]
7	Baicalin	F	Broth dilution	The 97 percent inhibitory concentrations (IC_{97}) of this extract to inhibit *S. intermedius, S. suis, P. aeruginosa and* β-*E. coli* were at the concentration of 2.48 12.43 1.83 and 2.31 mg/mL respectively.	[69]
	Ethanol			The half-maximal inhibitory concentrations (IC_{50}) of this extract to inhibit *S. intermedius, S. suis, P. aeruginosa and* β-*E. coli* were at the concentration of 1.30, 7.81, 39.20 and 66.85 mg/mL respectively.	
8	Methanol	L	Disc & diffusion methods	*Pseudomonas aeruginosa* (ZI, 0.7 cm) and *Bacillus subtilis* (ZI, 0.5 cm) at 0.36 g/mL	[70]
Antioxidant activities					
9	Acetone	L, S, T & R	FIA assay	Exhibited moderate to strong antioxidative activity with IC_{50} values of 8.01 ± 0.29 to 34.24 ± 1.77 µg/mL	[35]
	Dichloromethane	R & T		Exhibited moderate antioxidative activity with IC_{50} values of 31.57 ± 1.08 to 32.72 ± 0.41 µg/mL	
	5,6,7,4'-Tetrahydroxy-flavone (**10**) and 5,7,4'-trihydroxy-3'-methoxy-flavone (**12**)	NS		Exhibited antioxidative activity with IC_{50} values of 11.88 ± 0.06 and 33.45 ± 1.45 µM respectively	
10	Methanol:dichloromethane	WP	DPPH assay	IC_{50} value of 42.71 µg/mL.	[68]
11	Methanol	B	DPPH assay	Radical scavenging (IC_{50}) = 59.76 ± 0.969 µg/mL.	[66]
12	Dry extract	F	FRAP assay DPPH assay FRAP assay	57.14 ± 4.39 (µgVCEA/mg) &65.77 ± 4.99 (µgTREA/mg) 43.28 ± 0.67 scavenging activity (IC_{50}) µg/mL. EC_{50} value of 292.31 ± 0.06 µg/mL.	[71]
13	Water and Methanol (9:1)	L	DPPH assay	% Inhibition was 80% at 25 µg/mL.	[72]
14	Ethanol	L	4-NQO induced albino Wistar rats	Effect on induced oxidative stress LPO (1.8 mmol/100 g of wet tissue) SOD (3.6/mg protein) CAT (7.4 micromol of H_2O_2 consumed/min) GPx (25 mmol/g wet tissue) GSH (6.5 µg oxidized/min) at 200 mg/kg body weight.	[73]
15	Ethanol:water (6:4)	S	DPPH assay	IC_{50} values of 39.82 µg/mL.	[74]
Inflammatory activities					
16	Dry extract	F	LPS plus IFN-*c*-activated RAW264.7 cells.	Inhibit nitric oxide (NO) by 16% and interleukin (IL-6) by 62.99% at a dose of 200 µg/mL.	[48]
	Chrysin (**6**) and chrysin-6-C-β-D-glucopyranosyl-8-C-α-L-arabinopyranoside (**80**)	S		Inhibit NO by IC_{50} values 18.63 ± 0.91 and 28.69 ± 0.43 µM, respectively. Effect on chronic paw inflammation 48.57% (% inhibition).	
17	Ethanol: Water (6:4)	S	Carrageenan induced on Wistar albino rats	Effect on acute paw inflammation (% inhibition) 61.10% at 500mg/kg	[74]
18	Methanol	SB	Carrageenan induced on Swiss and Evans rats	Effect on acute paw inflammation (% inhibition) by 37.50%, 48.34% and 55.83%, for doses of 100, 200 and 400 mg/kg b.w. respectively.	[75]

19	Ethanol	S	Xylene-induced ear edema in Swiss albino mice	Effect on ear edema (% inhibition) 68.10% and 71.39% for 250 and 300 mg/kg b.w.	[76]
Immunomodulatory activities					
20	Ethyl acetate	B	DNCB sensi-tized Female Balb/c mice	Effective in suppressing the dermatitis scores by 23.26% and scratching frequency by 34.86% after treatment with 5% of the extract in cream formulation after 6 weeks.	[77]
Analgesic activities					
21	Ethanol:water (6:4)	S	Hot plate method on Wistar albino rats	Effect on pain induced and latency time (analgesia (%)) 64.04 ± 0.01% (120 min) and latency time (s)22.89 ± 0.26 (60 min) at 500 mg/kg.	[74]
22	Ethanol	SB	Hot Plate method on Swiss albino mice	Increase in latency period (%) 62.5 and 52.63 at 250 and 300 mg/kg, respectively.	[76]
23	Pet. ether and ethanol	L	Tail immer-sion method on Wister albino rats	Effect on latency (s) are 7.22 ± 0.07 and 9.02 ± 0.23 (after 45 min) respectively for a dose of 200 mg/Kg.	[78]
Anticancer activities					
24	Chrysin (**6**)	SD	MTT assay	Exhibited weak cytotoxic activity aganist A549, HepG2 and SW480 human cancer cell lines with IC_{50} values of 40.88 ± 3.85, 50.55 ± 2.59 and 91.60 ± 4.27 μM, respectively.	[48]
25	Water and methanol (9:1)	L	MTT assay	Effect on glioblastoma multiforme (GBM) cell growth, IC_{50} = 36 μg/mL.	[72]
26	Ethanol	SB	MTT assay	Effect on HepG2 cell lines, IC_{50} 64.1 ± 10.56 μg/mL.	[79]
27	Ethanol	L & F	SRB assay	Effect on MCF-7 human breast cancer cells after 48 h with IC_{50} values of 57.02 ± 2.85 μg/mL for the leaf extract and 131.30 ± 19.2 μg/mL for the fruit extract, respectively.	[80]
28	Methanol	L	MBA assay	IC_{50} for HeLa cell is 6.25 ± 1.06 μg/mL.	[81]
29	Ethanol	SD	MTT assay	Percentage of apoptosis for human hepatoma cell line SMMC-7721 is 24.77 ± 1.90%.	[82]
30	Methanol	L	MTT assay	IC_{50} values for primary chondrocytes is 357.78 ± 155.6 μg/mL and for SW 1353, chondrosarcoma cells was 490.49 ± 104.68 μg/mL.	[83]
31	Ethanol	F	MTT assay	SH-SY5Y cell viability was restored to 94.14 ± 2.79 and 98.35 ± 3.74% for 50 and 100 μg/mL, respectively from 76.83 ± 0.67% (treatment of 20 μM Aβ 25-35 for 24 h)	[84]
Antiproliferative activities					
32	Aqueous	B	Mitotic index of *Vigna radiata*	Changes in mitotic index (MI) (%) were 1.7 ± 0.125 and 2.09 ± 0.355, after 72 h at a dose of 250 and 2500 μg/mL, respectively.	[85]
Anthelmintic activities					
33	Methanol	S	*Hymenolepis diminuta*	Paralysis at 0.58 ± 0.04 h, followed by mortality at 1.19 ± 0.08h at a dose of 30 mg/mL.	[86]
			Hymenolepis diminuta worms in Albino rats of Wistar	Reduction in egg per gram (EPG) counts was 79.31% and 70.75% for worm counts at necropsy for juvenile at1000 mg/kg dose. While the EPG counts (74.56 %) at post-treatment days (days 26-28) and 66.75 % in worm count at necropsy of rats on day 36 for adults at1000 mg/kg dose.	
34	Methanol	B & F	Adult earth worms	Paralysis and mortality at 8.8min and 13.4 min (B) and 9 min and 14 min (F) at a dose of 100 mg/mL.	[87]
Hepatoprotective activities					
35	Ethanol	L	4-NQO induced stress in rats	Decrease the elevation of serum liver markers *viz*. ALT, ALP, AST and total bilirubin levels at 200 mg/kg body weight.	[73]
36	Aqueous and ethanolic	S	AKT-4 induced toxicity in Wistar rats	Significantly decrease ($p < 0.001$) levels of the biochemical parameters *viz*. ALT, AST, LDH and total bilirubin at a dose of 500 mg/kg.	[88]
37	Hydroethanol (3:1)	S	CCl_4 induced hepatotoxicity in Albino rats	Significant ($p \leq 0.001$) decrease of liver biomarkers *viz*. ALT, ALP, total bilirubin, total protein and γ-glutamyl transferase at 900 mg/kg body weight.	[89]
Antipyretic activities					
38	Ethanol	L	Brewer's yeast-induced pyrexia in Wister rats	Exhibited significant antipyretic activity, in which initial body temperature was 37.2 ± 0.11 °C and rectal temperature was 37.6 ± 0.27 °C after 30 min at a dose of 200 mg/kg body.	[78]

Antiulcer activities					
39	Ethanol (50%), EtOAc, chloroform, petroleum ether and *n*-butanol	S	Ethanol acid induced ulcer on Swiss & Evans rats	Exhibit high ulcer indexed ranging from (0.07 ± 0.007 to 0.87 ± 0.044) and ulcer inhibition (%) ranging from 86.12 to 98.60 at a dose of 100 and 200 mg/kg b.w./day.	[75]
Antidiarrheal activities					
40	Crude methanol and ethyl acetate fraction, dichloro-methane fraction, hexane fraction and carbon tetrachloride fraction	S & F	Castor oil induce diarrhea on adult Swiss albino mice	Cause reduction of diarrheal feces by 46.5%, 32.6%, 45.3%, 33.7%, 51.2%, respectively at a dose of 400 mg/kg.	[90]
Ameliorative activities					
41	Aqueous and *n*-butanol	R	Tobacco extracts induced damage on human lymphocytes	Cell viability (%) in the range of 36.42 ± 2.15 to 66.37 ± 22.67.	[91]
42	Ethanol	R	Dimethoate induced damage on human lymphocytes	On comet assay, cell viability (%) in the ranges of 87.08 to 98.75 for 20, 40 and 100 mM of dimethoate.	[92]
Radioprotective activities					
43	Petroleum ether and methanol	L	Presto blue assay	The sensitization enhancement ratio (SER) values calculated for 6 and 10 MV photon beams are 5.00 and 2.02 respectively, at a dose of 0.00001 mg/mL.	[93]
Cardioprotective activities					
44	Methanol (70%)	RB	Doxorubicin induced cardiomyopathy in Sprague dawley rats	Effect on myocardial lipid peroxidation levels for LPO (0.426 ± 0.011/mg protein), SOD (0.197 ± 0.008/mg protein), GPx (31.31 ± 1.60/mg protein), GSH (4.67 ± 0.167/mg protein), at 400 mg/kg b.w.	[94]
Antiadipogenesis activities					
45	Ethyl acetate	B	Oil red 'O' in 3T3-L1 cells during adipogenesis	Reduced lipid accumulation by 59.12 ± 1.66% at 50 µg/mL.	[95]
	Oroxylin A (**29**), Chrysin (**6**) and Baicalein (**4**)			Inhibited lipid accumulation in 3T3-L1 preadipocytes (75.00 ± 5.76%, 70.21 ± 4.23% and 77.21 ± 5.49%), respectively, at a dose of 50 µM.	
46	95% Ethanol	FP		The IC_{50} and IC_{60} for lipid accumulation were 201.26 ± 10.00 and 237.72 ± 14.96 µg/mL, respectively.	[96]
Antidiabetic activities					
47	Aqueous Ethanol (90%)	SD	Alloxan-induced diabetic Male SD rats and Kunming mice	Significant inhibitory activity against α-glucosidase with IC_{50} = 43.4 ± 0.73 µg/mL.	[97]
	Baicalein (**6**)			IC_{50} value of 25.9 ± 0.412 µg/mL.	
	Baicalein-7-O-glucoside (**46**)			37.3% inhibition at 40 µg/mL.	
48	Ethanol: water 90%	SD	Streptozotocin and high-fat diet induced diabetes in Kunming mice	Reduce the risk of diabetes by 75% on treatment of combination of acarbose and extract in the ratio of 4:200mg/kg.	[98]
49	Oroxin-A (**46**)	SD		Reduced the risk of diabetes by 66.7% at 200 mg/kg.	[99]
Antiepileptic activities					
50	Methanol	L	MES and PTZ induced seizure in albino Wistar rats	Show significant decrease in time of myoclonic jerk 6.67 ± 0.56 and tonic flexation 4.67 ± 0.56 in PTZ model and decrease in time of tonic convulsion 2.33 ± 0.21 and clonic expansion 4.67 ± 0.56 in MES model at 200 mg/kg, i.p.	[100]
Wound healing activities					
51	Ethanol	SB	Deep dermal excision wound on Swiss albino mice	Rise in wound contraction and mean healing time (MHT) with eight days lesser as compared to 27 days for PEG treated and the highest wound contraction for 10% extract.	[101]
Other activities					
52	Methanol	B	Starch-iodine method	IC_{50} value for α-amylase inhibition activity is 192 ± 0.085 µg/mL.	[66]
53	Dichloromethane and Ethyl acetate	B	PNPP method	Pancreatic lipase (PL) inhibition was (88.73 ± 2.52 and 89.12 ± 6.87%) respectively, at 250 µg/mL dose.	[95]
	Oroxylin A (**29**), chrysin (**6**) and baicalein (**4**)			PL inhibition were (69.86 ± 2.96%, 52.08 ± 2.14% and 45.06 ± 2.42%) for **29**, **6** and **4** respectively, at 250 µg/mL dose.	

S = stem, SB = stem bark, SK = stalk, L = leave, SD = seed, R = root, RB = root bark, F = Fruit, FP = fruit pod, FL = Flower, B = bark, P = pedicel, C = callus, T = Twig, WP = whole plant, NS = not specified & PLT= plantletse, B = bark.

Oroxylum indicum stem bark. They observed that all doses of methanolic extract showed substantial anti-inflammatory activity, which was significant ($p < 0.01$). The results after 6 h showed that standard drug ibuprofen (20 mg/kg b.w.) could inhibit paw edema by 53.33% and all methanolic extracts (100, 200 and 400 mg/kg b.w.) inhibit edema in mice paw by 37.50%, 48.34% and 55.83% separately. These findings suggest that *O. indicum* may be useful in management of chronic inflammatory conditions like arthiritis.

Immunomodulatory activities: The cream formulations of *O. indicum* bark extract in ethyl acetate in different concentrations (0, 1.25, 2.5, 3.75 and 5%) were topically applied onto the dorsal skin of 2,4-dinitrochlorobenzene (DNCB)-sensitized BALB/C mice once a day for 6 weeks as performed by Trang & Son [77]. They found that the extract at 5% was significantly effective in suppressing the dermatitis scores by 23.26% ($p < 0.001$) and reducing scratching frequency by 34.86% ($p < 0.001$) compared to the 51.38% of positive control (tacrolimus (0.1%)). Thus, the use of *O. indicum* in treatments of skin diseases has experimental confirmation. However, in depth studies on immune-modulatory effects of bioactive components must support the utilization of this important medicinal plant.

Analgesic activities: The analgesic activity of *O. indicum* stem bark was assessed using the hot plate method in Swiss albino mice by Lalrinzuali *et al*. [76]. The administration of ethanolic extract at a dose of 300 mg/kg exhibited the highest activity (62.5% inhibition) as compared to positive control diclofenac showing higher analgesic activity (76.31% inhibition) at a dose of 20 mg/kg b.w. The leaves of *O. indicum* also possess significant analgesics activity. The extract of petroleum ether and ethanol showed analgesic effect having latency(s) values of 7.22 ± 0.07 and 9.02 ± 0.23, respectively, after 45 min for a dose of 200 mg/kg as compared to aspirin (latency(s) was 10.12 ± 0.16 in a dose of 50 mg/kg). As plant products have minimum side effects compared to opioid and non-opioid analgesics [103], proper formulations based on this plant may be helpful in near future.

Anticancer/tumor activities: The stem bark of *O. indicum* extracted in ethanol showed significant antiproliferative effect on the HepG2 cell lines with IC_{50} = 64.1 µg/mL [79]. Baicalein **2**, the major compound isolated from *O. indicum* is known to possess anticancer activity as reported by Lodh & Swamy [104]. Chrysin (**6**), an important flavonoid of *O. indicum* was shown to increase p53 protein expression and decrease cell viability in MCF7 cells [105]. Chrysin participates in the inactivation of the ATM-Chk2 pathway and acting as an anticancer drug through the activation of p53 without damaging DNA. Thus, *O. indicum* is a potential candidate for plant based chemotherapeutic drugs for the treatment of various forms of cancer. However, further research is necessary before the clinical use of this plant. In order to obtain a better understanding of the compounds present in the plant and their biological activities related to cancer treatment more studies would be valuable.

Antiproliferative activities: The antiproliferative activity of aqueous bark extract of *O. indicum* on *Vigna radiata* seedlings was carried out by Chetry & Bharali [85]. The treatment with plant extracts (250, 500, 1000 and 2500 µg/mL) for 24, 48 and 72 h significantly inhibits the germination of seeds, roots and shoots growth and reduced the mitotic index. It indicates that the treatment with *O. indicum* aqueous stem bark extract (250 and 2500 µg/mL) significantly decreased the rate of mitotic index (1.7 ± 0.125 and 2.09 ± 0.355, respectively, after 72 h) of *V. radiata* root apical meristem cells. The standard drug colchicine (50 µg/mL) also significantly reduced the mitotic index (2.53 ± 0.375) in all the experimental groups.

Anthelmintic activities: The *in vitro* and *in vivo* anthelmintic effects of *O. indicum* stem bark extract in methanol on *Hymenolepis diminuta* was conducted by Deori *et al*. [86]. The *in vitro* study revealed the significant anthelmintic activities of *O. indicum*. The *in vivo* effects of extract on *H. diminuta* worms in rats also show dose-dependent ($p < 0.001$) effects. In the case of juvenile worms, a single 1000 mg/kg b.w. dose of extract, administered for 5 days after post-inoculation of cysticercoids revealed up to 79.31% reduction in eggs per gram (EPG) counts and 70.75% reduction in worm counts at necropsy. However, for reference drug PZQ (10 mg/kg) for the same duration showed a reduction in EPG counts up to 89.34% and worm counts up to 83.50%. Against the adult worms, 74.56% reduction in the EPG counts at post-treatment days (days 26-28) and 66.75% reduction in worm count at necropsy of rats on day 36 after 5 days of treatment with extract. At the same dose, the effects of PZQ were slightly better with 90.33% reduction in EPG counts and 87.50% reductions in worm counts of animals. Thus, herbal remedy based on *O. indicum* can be explored in the future for the treatment of intestinal-helminthic infections.

Hepato-protective activities: Hepatotoxicity induced by oral dosing of antitubercular drugs *viz*. AKT-4 for 90 days to Wistar rats was studied [88]. Treatment with both aqueous and ethanolic stem extracts of *O. indicum* as well as standard drug silymarin (100 mg/kg) was performed for 30 days. Both the aqueous and ethanolic extracts of *O. indicum* significantly ($p < 0.05$) restored the serum enzyme levels ALT, AST, LDH and T Bil, at a dose of 500 mg/kg. It showed absence of any remarkable pathological and metabolic changes in the liver sections of treated groups and mRNA expression was drastically increased in disease induced group as compared to normal control. Hence, *O. indicum* can be recommended for clinical test and may be considered as an effective supplement for the patients taking various drugs having concerned in liver toxicities.

Antipyretic activities: Samarath & Panda [78] reported that ethanolic extract of *O. indicum* leaf showed significant antipyretic activity at a dose of 200 mg/kg b.w. In their experiment, rectal temperature was found to be 37.6 ± 0.27 ºC after 30 min of treating with the extract from the initial body temperature of 37.2 ± 0.11 ºC. While treating with paracetamol at a dose of 100 mg/kg, rectal temperature was 38.2 ± 0.07 ºC from same initial body temperature of 37.2 ± 0.11 ºC. Thus, the antipyretic potential of *O. indicum* could be further analyzed.

Antiulcer activities: Antiulcer activity of the ethanolic extract of *O. indicum* stem bark and its different fractions *viz*. petroleum ether, chloroform, ethyl acetate and *n*-butanol were performed by Begum *et al*. [75]. For treatment with doses of

100 and 200 mg/kg body weight per day, stomachs were examined with gastric lesion and mildly notable blood clot formation due to the injury of cell line layer. However, for the dose of 400 mg/kg, no noticeable perforation, blood clot formation and cell damage were observed. Stomachs were healthy and in fine fettle compared to the control group. But *n*-butanol and petroleum ether showed 0.07 ± 0.007 and 0.27 ± 0.011 ulcer index with inhibitory percentage of 99 and 96, respectively. Ethyl acetate showed a lower percentage of inhibition 86 with ulcer index 0.87 ± 0.044. For standard drug omeprazole, there was 88.70% inhibiting effect against ulcer. More study on antiulcer activities of *O. indicum* will be worthy in near future.

Antidiarrheal activities: The *in vivo* antidiarrheal activity of *O. indicum* was demonstrated by Mamun-Or-Rashid *et al*. [90]. The methanolic crude extract of bark and fruits and its different fractions (ethyl acetate fraction, dichloromethane fraction, hexane fraction, carbon tetrachloride fraction) cause reduction of diarrheal faeces by 46.5%, 32.6%, 45.3%, 33.7% and 51.2%, respectively, at a dose of 400 mg/kg body weight per day in comparison to standard drug loperamide (82.6%). These indicated that *O. indicum* possess antidiarrheal activity.

Ameliorative activities: The ameliorative activity of the plant was assessed by Soni *et al*. [92]. In MTT assay, the viability of control cells was taken as 100% and after 2 h of exposure to various concentrations of dimethoate, there was dose dependent decrease in viability. The viability of treated cells increased in the ranges of 87.08 to 98.75 after incubation with 50% of the root extract of *O. indicum*. Thus, this plant can be explored for agricultural purpose as to overturn the cellular damage caused by the various organic insecticides.

Radioprotective activities: The radio-protective activities of *O. indicum* leaf extracted in petroleum ether and methanol were investigated by Rahman *et al*. [93]. The cytotoxic effects of *O. indicum* extracts were determined *in vitro* using HeLa cells. The cells with non-toxic concentration of *O. indicum* extracts were irradiated with 6 MV and 10 MV photon beams. The extracts with maximum concentration of 0.01 mg/mL were found non-toxic to HeLa cells. However, the combination of *O. indicum* extracts and irradiation were found to reduce the cells survival which indicates radiosensitization effects. The sensitization enhancement ratio (SER) calculated indicate higher radiosensization observed for 6 MV photon beams compare to 10 MV photon beams. SER also increased at higher *O. indicum* concentration. The scope of *O. indicum* based radiosensitizer to enhance the therapeutic competence in radiation therapy of cancer treatment will be fruitful.

Cardioprotective activities: The cardioprotective effect of 70% methanolic extract of *O. indicum* root bark against doxorubicin induced cardiomyopathy in female Sprague Dawley rats was performed by Menon *et al*. [94]. Pre-treatment of the animals with *O. indicum* extract recuperated near normalcy in the SOD, GSH and GPx levels, when compared to control animals treated with doxorubicin alone. Thus, the capability of *O. indicum* root bark extract in shielding the damaging and devastating effects of cumulative administration of doxorubicin (30 mg/kg of animal b. w.) in experimental rats was experimentally significance. This extends the scope of exploring active fractions from *O. indicum* having cardioprotective activity and for therapeutic development to treat cardiac complications.

Antiadipogenesis activities: The ethyl acetate extract of *O. indicum* bark possess strongest antiadipogenesis with lipid accumulation value of 59.12 ± 1.66% as compared to 42.07 ± 0.97% of standard drug quercetin at 50 µg/mL dose in 3T3-L1 pre-adipocytes as reported by Mangal *et al*. [95]. Further, oroxylin A (**29**), chrysin (**6**) and baicalein (**3**) isolated from *O. indicum* bark inhibited lipid accumulation (75.00 ± 5.76%, 70.21 ± 4.23% and 77.21 ± 5.49%, respectively) at a dose of 50 µM. Recently, Hengpratom *et al*. [106] reported the antiadipogenesis of the 95% ethanolic extract (at a dose of 200 µg/mL) of *O. indicum* fruit pods. The downregulation of peroxisome proliferator-activated receptor-gamma 2 (PPARγ2) and lipogenic genes controlling adipogenesis, including sterol regulatory element-binding proteins-1c (SREBP-1c), fatty acid synthetase (FAS) as well as glucose transporter (GLUT4) were the probable mechanism for the activity. This leads to diminish in adipokines marker secretion from adipocytes. These results justify for the antiobesity potential of *O. indicum* and its flavonoids.

Antidiabetic activities: Pre-diabetes is a stage where blood glucose levels are above normal but lower than diabetes thresholds. It will ultimately develop to diabetes up to 70% of individuals if it is left untreated. The synergistic effects of acarbose and *O. indicum* seed extract in pre-diabetic mice induced by streptozotocin and high-fat-diet was assessed by Sun *et al*. [98]. The combined drugs could reduce the dose of acarbose by 80% and reduce the risk of diabetes by 75%, which was one-fold higher than acarbose monotherapy. They reported that combined drugs could prevent and reverse pre-diabetes from developing into diabetes by inhibiting α-glucosidase. They further isolate oroxin A (**46**) from *O. indicum* seed and reported that it could reduce the relative risk of progression from pre-diabetes to diabetes by 66.7% without inducing weight gain or hepato-toxicity [99]. It could improve the complications of pre-diabetes, such as lipid metabolism dysfunction and liver injury. And, isolate oroxin A (**46**) was a partial PPARγ agonist that could activate PPARγ transcriptional activation *in vitro* and *in vivo*. It also exhibited an inhibitory activity against α-glucosidase. Hence, *O. indicum* could be further exploited for designing plant-based agents or dietary supplements in treating diabetes.

Antiepileptic activities: The methanolic extract of *O. indicum* leaves show significant antiepileptic activities by decrease in time of myoclonic jerk and tonic flexation in pentylenetetrazole (PTZ) model and decrease in time of tonic convulsion and clonic expansion in maximal electro shock (MES) model. The extract also possessed CNS depressant activity which could be therapeutically useful in management of epilepsy as reported by Rathod *et al*. [100]. The composition of 10-15% w/w of oroxylin A (**46**), 10-25% w/w of baicalein (**4**) and 2-10% w/w of chrysin (**6**) showed dose dependency in reducing the plethora of seizure activities induced by kainic acid (250 and 500 mg/kg, oral administration). It significantly improved the reduced locomotion, increased muscle rigidity, salivation,

teeth grinding, clonus and repetitive head/leg movement which were evaluated as a part of Racine scores as patented by Majeed & Nagabhushanam [107].

Wound healing activities: The *in vivo* wound healing activity of the stem bark ethanolic extract of *O. indicum* against Swiss albino mice was recently reported by Lalrinzuali *et al.* [101]. The topical application of the extract accelerated healing of regenerating wounds and reduced the mean healing time (MHT) by 8 days lesser than that of PEG treated with 27 days and the highest wound contraction was recorded for 10% of extract. It also increased the syntheses of collagen and DNA and reduced lipid peroxidation (LOO) in the regenerating wounds. The increased wound healing ability of extract may be due to its ability to scavenge free radicals and increase cell proliferation which would have been able to raise the collagen and DNA syntheses leading to early closure of the wound. It has also reduced the expression of nuclear factor-kappaB (NF-κB) and cyclooxygenase-II (COX-II) in regenerating wounds leading to accelerated healing of wounds. These experimentally substantiate the uses of *O. indicum* as a wound healing agents by the traditional healers.

Other activities: Apart from listed activities, methanol extract of *O. indicum* bark inhibit α-amylase activity with IC_{50} = 192 ± 0.085 µg/mL [66]. The major compounds isolated from it *viz.* oroxylin A (**29**), chrysin (**6**) and baicalein (**4**) also inhibit pancreatic lipase with inhibition % ranging from 45.06 ± 2.42 % to 69.86 ± 2.96% at a dose of 250 µg/mL [96]. The effect of *O. indicum* bark extracted in acetone was reported to influence the esterase intensity and increase in the silk yield in *Bombyx mori* [108]. *O. indicum* also exhibit other biological activities like antiarthritic, antigout, anticolitis, antileishmanial and nephroprotective as summarized in Table-2.

Toxicology: The major drawback of employing traditional medicines is the lack of adequate supporting scientific information on the level of quality, safety, efficacy and toxicity. The toxicity study of 90% ethanol-water extract of *O. indicum* seed was performed on male Kunming mice (16-20 g). The mice were administered 0-5 g/kg extract b.w. per day for two weeks. It was confirmed that 2 g/kg of extract was safe for the mice [106]. Further, the acute toxicity study of the ethanol: water (60:40) extract of *O. indicum* stem bark was assessed in adult female Wistar albino rats. They were fasted for 16 h and different concentrations of the extract (250, 500, 1000, 2000 and 2500 mg/kg body weight p.o.) were administered to all the animals. None of the animals were dead during the toxicity studies. Thus, the LD_{50} of the extract was found to be safe up to a dose of 2500 mg/kg body weight of the animal [74]. These studies confirmed that ethanol:water and methanol extracts of seed, root and stem bark of *O. indicum* are safe for oral administration in traditional uses in treating various diseases.

Conclusion

In this review, relatively detailed studies on the phytochemical and pharmacological information on the use of *Oroxylum indicum* plant are summarized. The interesting properties showed in this review make *O. indicum* a plant with potential applications in different fields. Particularly, the biological activities showed by its extracts or isolated compound(s) encourage examining the possible molecular interaction for antimicrobial, antioxidant and anticancer effects. Furthermore, the very promising results on antidiabetic as well as the analgesic, antidiarrheal and antiepileptic effects obtained in *in vivo* experiments lead to profound the scientific knowledge on this plant. Thus, more scientific and extensive studies are very much essential to enhance the knowledge about the pharmacological activities, chemical constituents and efficacy of *O. indicum* extracts as well as about its bioactive metabolites. Owing to the indiscriminate collection, over exploitation and uprooting of whole plants bearing roots, this plant has become vulnerable. To control this menace, method like, *in vitro* regeneration of plant through tissue culture, micropropagation protocols using *in vitro* generated plantlet be implemented for the optimal conservation of this plant. Toxicological studies are required to address the concerned studies for mycotoxin, heavy metal and pesticide concentrations as well as the general toxicity of *O. indicum* extracts and purified compounds. Attempts need to be made to gain regulatory approval of *O. indicum* preparations as food supplements or medicinal drugs.

ACKNOWLEDGEMENTS

One of the authors, OMS is grateful to the DBT, (BT/PR25414/NER/95/1183/2017), Government of India for the financial assistance.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

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