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Bioactivities of extracts and phytochemicals of *Indigofera aspalathoides* Vahl ex DC.

by ***Authinarayanan Rajesh*** *(The Tamil Nadu Dr. M.G.R. Medical University, Chennai, India),* ***Saravanan Vivekanandarajah Sathasivampillai*** *(KnowledgeLink Group, Inc., Waltham, MA 02451, USA), and* ***Pholtan Rajeev Sebastian Rajamanoharan*** *(Eastern Provincial Herbal Garden Management Center, Trincomalee, Sri Lanka and Department of Siddha Toxicology, The Tamil Nadu Dr. M.G.R. Medical University, Chennai, India)*

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Corresponding author: vivekanandarajahs@yahoo.co.uk
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ABSTRACT

Indigofera aspalathoides Vahl ex DC. belongs to the *Fabaceae* family. *I. aspalathoides* is applied to heal tumors, inflammations, diabetes, leprosy, and kidney illnesses in traditional medicines. Compounds including kaempferol, kaempferol 5-O-β-D-glucopyranoside, 5,4'-dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone, indigocarpan, and mucronulatol have isolated from this plant species. Hitherto, there is no comprehensive review available regarding the reported bioactivities of *I. aspalathoides*. Thus, this article goals to analyze, summarize and document the published bioactivities-related publications. Electronic databases the Web of Science, Scopus, ScienceDirect, and PubMed used to find relevant publications from 1900 to December 2020. Thus far, only *in vivo* and *in vitro* scientific evidence levels of bioactivities are available. *I. aspalathoides* holds such as anti-inflammatory, anticancer, antihepatotoxic, anti-arthritic, immunomodulatory, and antidiabetic properties. Overall, immunomodulatory, anti-inflammatory, and anticancer compounds have been isolated from this plant species Therefore, additional bioactivity and phytochemical-related researches would need to perform to generate more scientific evidence for other applications. This work will be useful for further bioactivity and phytochemical studies using this plant species.

Keywords: *Indigofera aspalathoides, Fabaceae, Sri Lanka, Siddha Medicine, bioactivities*

1. Introduction

Indigofera aspalathoides Vahl ex DC. is an herb/shrub belonging to the *Fabaceae* family. It is native to Sri Lanka and India and utilized for domestic and medicinal uses. It is used to treat tumors, toothache, abscesses, gastric hyperacidity, stomach ulcers, inflammations, psoriasis, syphilis, leprosy, erysipelas, dandruff, aphthae, eczema, hepatitis, kidney illnesses in traditional medicinal systems (Chopra et al., 1992; Khare, 2007; Kirtikar & Basu, 2005). *I. aspalathoides* is called Sivanaarvembu (சிவனார்வேம்பு) and Iraivanvembu (இறைவன்வேம்பு) in Tamil / Siddha Medicine, Shivanimba and Nili in Ayurveda Medicine, and Wiry Indigo in English (Khare, 2007). Particularly, the whole plant of *I. aspalathoides* is employed to treat diabetes in Sri Lankan Siddha Medicine (Saravanan V. Sathasivampillai, Rajamanoharan, & Heinrich, 2018; Saravanan V. Sathasivampillai, Rajamanoharan, Munday, & Heinrich, 2017; Saravanan Vivekanandarajah Sathasivampillai, Rajamanoharan, Heinrich, & Munday, 2015). Compounds including quercetin, kaempferol, kaempferol 5-O-β-D-glucopyranoside, 5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone, indigocarpan, and mucronulatol were isolated from *I. aspalathoides* (Balasubramanian, Narayanan, Kedalgovindaram, & Rama, 2007; Selvam et al., 2004; Subramaniam Swarnalatha, Umamaheswari, & Puratchikody, 2015).

Hitherto, there is no systematic review available regarding the reported bioactivities of *I. aspalathoides*. Thus, this article goals to analyze, summarize and document the published bioactivities-related publications. This review would be advantageous for those who are interested to conduct further bioactivity and phytochemical researches using this plant species.

2. Methods

Electronic databases such as the Web of Science, Scopus, ScienceDirect, and PubMed were employed to find relevant publications of *I. aspalathoides* from 1900 to December 2020. "*Indigofera aspalathoides*" has been used as a search term, and the results were then refined to the fields like Pharmacology, Toxicology, and Pharmaceutics, Medicine, Biochemistry, Genetics, and Molecular Biology, Chemistry, Agricultural Science, and Biological Science, and Multidisciplinary.

3. Results and discussion

3.1. Reported bioactivities of I. aspalathoides

Table 1 contains the level of scientific evidence, bioactivity, part, extract / compound, assay / model, dose / concentration, and reference of reported studies. Thus far, only *in vivo* and *in vitro* levels of scientific evidence of bioactivities are available. While a larger number of investigations have been carried out in *in vivo* models. *I. aspalathoides* holds antioxidant, antibacterial, anti-inflammatory, anticancer, antihepatotoxic, anti-arthritic, immunomodulatory, and antidiabetic properties (Abraham et al., 2010; Amala Bhaskar, Ganga, Arivudainambi, & Santhanam, 1982; Balasubramanian et al., 2007; Bhagavan, Arunachalam, Dhasarathan, & Kannan, 2013; Bhuvaneswari & Balasundaram, 2006; Christina et al., 2003; Claimer, Mahesh, Sinilal, Rao, & Thangadurai, 2012; S. S. Kumar, Karrunakaran, Rao, & Balasubramanian, 2010; S. S. Kumar, Rao, & Balasubramanian, 2011, 2012; T. T. Kumar et al., 2018; Mahajan, Gnana Oli, Jachak, Bharate, & Chaudhuri, 2016; Nanjian et al., 2015; Philips et al., 2010; Rajagopal, Narasimman, & Periyakali Saravana, 2016; Rajendran, Shirwaikar, & Srinivasan, 2013; Rajkapoor, Anandan, & Jayakar, 2003; Rajkapoor, Jayakar, Kavimani, & Murugesh, 2006; Rajkapoor, Jayakar, & Murugesh, 2004; Rajkapoor et al., 2009, 2009; Ravi et al., 2018; Selva Kumar, Ram Krishna Rao, & Balasubramanian, 2011; Selvam et al., 2004; Sivagnanam, Rao, & Balasubramanian, 2013; S. Swarnalatha & Puratchikody, 2014; Subramaniam Swarnalatha et al., 2015). Among these activities, majority of the investigations were carried out to study anticancer effects. Leaves and stems have been used separately in more researches. Leaves showed antioxidant, antibacterial, antioxidant, and anticancer activities, while stems unveiled anticancer, antihepatotoxic, anti-arthritic, and anti-inflammatory effects. Ethanol was utilized to prepare the extracts in most of the investigations. So far, four bioactive compounds have been isolated, and they own immunomodulatory (Kaempferol 5-O-β-D-glucopyranoside) (S. Swarnalatha & Puratchikody, 2014), anti-inflammatory (Indigocarpan and Mucronulatol) (Selvam et al., 2004), and anticancer (5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone and Indigocarpan) (Balasubramanian et al., 2007) activities. Interestingly, Indigocarpan holds both anti-inflammatory and anticancer effects. Hitherto, reported anticancer, anti-inflammatory, and antidiabetic activity researches provide scientific evidence for treating tumors, inflammations, and diabetes in traditional medicines. Significant studies showed bioactivities at the lowest concentration / dose are only discussed below.

TABLE 1. Reported bioactivities of *I. aspalathoides*

Level of scientific evidence	**Bioactivity**	**Part**	**Extract / compound**	**Assay / model**	**Dose / concentration**	**Reference**

Level of scientific evidence	Bioactivity	Part	Extract / compound	Assay / model	Dose / concentration	Reference
In vivo	Anti-arthritic	Stem	Ethanol (95%)	Complete Freund's adjuvant-induced arthritis	250 mg/kg	Rajkapoor et al. (2009)
In vivo	Anticancer	Aerial	Water	20-Methylcholanthrene induced fibrosarcoma	250 mg/kg	Kumar et al. (2012, 2011, 2010, 2009); Selva Kumar et al. (2011); Sivagnanam et al. (2013)
In vivo	Anticancer	Root	Ethanol	N-nitrosodiethylamine-induced hepatocarcinogenesis	100 mg/kg	Claimer et al. (2012)
In vivo	Anticancer	Leaf	Ethanol (95%)	DMBA-induced oral carcinoma	250 mg/kg	Abraham et al. (2010)
In vivo	Anticancer	Stem	Ethanol	Ehrlich ascites carcinoma tumor, N-nitrosodiethylamine-induced phenobarbitol promoted liver tumor	250 mg/kg	Rajkapoor et al., (2004)
In vivo	Anticancer	Whole plant	Ethanol	Dalton's ascitic lymphoma	400 mg/kg	Christina et al. (2003)
In vivo	Antidiabetic	Whole plant	Water	Streptozotocin-nicotinamide induced diabetic	250 mg/kg	Rajendran et al. (2013)
In vivo	Antihepatotoxic	Stem	Ethanol	Carbon tetrachloride-induced hepatic damage	NS	Rajkapoor et al. (2006)
In vivo	Anti-inflammatory	NS	Ethanol	Carrageenan-induced rat paw oedema	250 mg/kg	Rajkapoor et al. (2003)
In vivo	Anti-inflammatory	NS	NS	NS	NS	Amala Bhaskar et al. (1982)
In vivo	Anti-inflammatory	Stem	Methanol	Carrageenan-induced rat paw oedema	250 mg/kg	Bhagavan et al. (2013)
In vivo	Anti-inflammatory	NS	Indigocarpan	Carrageenan-induced rat paw oedema	125 mg/kg	Selvam et al. (2004)

Level of scientific evidence	**Bioactivity**	**Part**	**Extract / compound**	**Assay / model**	**Dose / concentration**	**Reference**
In vivo	Immunomodulatory	Aerial	Kaempferol-5-O-β-D-glucopyranoside	Cyclophosphamide-induced myelosuppression	50 mg/kg	Swarnalatha and Puratchikod (2014)
In vivo	Immunomodulatory	Aerial	Kaempferol 5-O-β-D-glucopyranoside	Rat	10 mg/kg	Swarnalatha et al. (2015)
In vitro	Antibacterial	Leaf	Ethanol	*Escherichia coli, Salmonella typhi, Staphylococcus aureus*	NS	Kumar et al. (2018)
In vitro	Antibacterial	NS	Ethanol	*Aeromonas hydrophila*	2.16 mg/ml (MIC)	Bhuvaneswari and Balasundaram (2006)
In vitro	Antibacterial	NS	Methanol	NS	NS	Rajagopal et al. (2016)
In vitro	Anticancer	NS	Indigocarpan	Human colorectal adenocarcinoma LS174T cell	180 μM (IC_{50})	Mahajan et al. (2016)
In vitro	Anticancer	Stem	5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone	Ovarian cancer cell OVCAR-5	4 μM (GI_{50})	Balasubramanian et al. (2007)
		Stem	5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone	Breast cancer cell NCI/ADR-RES, Ovarian cancer cell SK-OV-3	4.06 μM (GI_{50})	
		Stem	5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone	Renal cancer cell TK-10	4.14 μM (GI_{50})	
		Stem	5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone	Renal cancer cell 786-0	4.29 μM (GI_{50})	

Level of scientific evidence	Bioactivity	Part	Extract / compound	Assay / model	Dose / concentration	Reference
		Stem	5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone	Skin cancer melanoma cell SK-MEL-2	4.32 µM (GI_{50})	
		Stem	5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone	Central nervous system cancer cell SNB-19	4.35 µM (GI_{50})	
		Stem	5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone	Lung cancer cell NCI-H322M	4.37 µM (GI_{50})	
		Stem	5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone	Colon cancer cell HCT-15, Colon cancer cell KM12	4.4 µM (GI_{50})	
		Stem	5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone	Lung cancer cell EKVX	4.42 µM (GI_{50})	
		Stem	5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone	Colon cancer cell HCC-2998	4.43 µM (GI_{50})	
		Stem	5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone	Central nervous system cancer cell SF-295	4.44 µM (GI_{50})	
		Stem	5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone	Lung cancer cell HOP-62, Colon cancer cell SW-620, Renal cancer cell A498, Skin cancer melanoma cell SK-MEL-28,	4.45 µM (GI_{50})	

Level of scientific evidence	Bioactivity	Part	Extract / compound	Assay / model	Dose / concentration	Reference
				Skin cancer melanoma cell SK-MEL-5		
		Stem	5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone	Breast cancer cell MCF7, Central nervous system cancer cell SF-539, Prostate cancer cell PC-3	4.46 µM (GI_{50})	
		Stem	5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone	Skin cancer melanoma cell MALME-3M	4.47 µM (GI_{50})	
		Stem	5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone	Central nervous system cancer cell SF-268	4.48 µM (GI_{50})	
		Stem	5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone	Colon cancer cell HCT-116, Lung cancer cell A549/ATCC	4.49 µM (GI_{50})	
		Stem	5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone	Leukemia human tumor cell CCRF-CEM	4.5 µM (GI_{50})	
		Stem	5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone	Lung cancer cell NCI-H226, Renal cancer cell ACHN	4.51 µM (GI_{50})	
		Stem	5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone	Central nervous system cancer cell U251, Colon cancer cell HT29	4.52 µM (GI_{50})	

Level of scientific evidence	Bioactivity	Part	Extract / compound	Assay / model	Dose / concentration	Reference
		Stem	5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone	Breast cancer cell HS 578T, Colon cancer cell COLO 205, Ovarian cancer cell OVCAR-4	4.53 µM (GI_{50})	
		Stem	5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone	Breast cancer cell MDA-MB-435	4.54 µM (GI_{50})	
		Stem	5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone	Leukemia human tumor cell RPMI-8226, Ovarian cancer cell OVCAR-8, Skin cancer melanoma cell LOX IMVI	4.55 µM (GI_{50})	
		Stem	5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone	Lung cancer cell NCI-H460, Renal cancer cell CAKI-1, Renal cancer cell SN12C	4.56 µM (GI_{50})	
		Stem	5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone	Leukemia human tumor cell K-562	4.58 µM (GI_{50})	
		Stem	5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone	Breast cancer cell BT-549	4.6 µM (GI_{50})	
		Stem	5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone	Lung cancer cell NCI-H522, Prostate cancer cell DU-145, Renal cancer cell RXF393	4.62 µM (GI_{50})	
		Stem	5,4'-Dihydroxy 6,8-dimethoxy 7-	Renal cancer cell UO-31	4.64 µM (GI_{50})	

Level of scientific evidence	Bioactivity	Part	Extract / compound	Assay / model	Dose / concentration	Reference
			O-rhamnosyl flavone			
		Stem	5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone	Breast cancer cell T-47D	4.65 μM (GI_{50})	
		Stem	5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone	Ovarian cancer cell OVCAR-3	4.67 μM (GI_{50})	
		Stem	5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone	Central nervous system cancer cell SNB-75, Lung cancer cell NCI-H23	4.69 μM (GI_{50})	
		Stem	5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone	Leukemia human tumor cell SR	4.71 μM (GI_{50})	
		Stem	5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone	Ovarian cancer cell IGROV-1	4.74 μM (GI_{50})	
		Stem	5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone	Breast cancer cell MDA-MB-231/ATCC, Skin cancer melanoma cell UACC-62	4.78 μM (GI_{50})	
		Stem	5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone	Leukemia human tumor cell MOLT-4	4.81 μM (GI_{50})	

Level of scientific evidence	**Bioactivity**	**Part**	**Extract / compound**	**Assay / model**	**Dose / concentration**	**Reference**
		Stem	5,4'-Dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone	Skin cancer melanoma cell UACC-257	5.4 µM (GI_{50})	
In vitro	Antifungal	Leaf	Ethanol	*Aspergillus flavus*, *Aspergillus niger*, *Aspergillus ochraceous*	NS	Kumar et al. (2018)
In vitro	Anti-inflammatory	NS	Indigocarpan	Cyclooxygenase-1 inhibitory	30.5 µM (IC_{50})	Selvam et al. (2004)
		NS	Indigocarpan, Mucronulatol	Cyclooxygenase-2 inhibitory	100 µg/ml	
		NS	Mucronulatol	Cyclooxygenase-1 inhibitory	51.9 µM (IC_{50})	
In vitro	Antioxidant	Leaf	Chloroform	ABTS radical scavenging	8.6 µg/ml (IC_{50})	Philips et al. (2010)
		Leaf	Chloroform	DPPH radical scavenging	10.6 µg/ml (IC_{50})	
		Leaf	Chloroform	NO radical scavenging	29.95 µg/ml (IC_{50})	
		Leaf	Chloroform	OH radical scavenging	21.85 µg/ml (IC_{50})	
		Leaf	Ethanol	DPPH radical scavenging	18.1 µg/ml (IC_{50})	
		Leaf	Ethanol	NO radical scavenging	35.2 µg/ml (IC_{50})	
		Leaf	Ethanol	OH radical scavenging	32.5 µg/ml (IC_{50})	
		Leaf	Ethanol	ABTS radical scavenging	12.1 µg/ml (IC_{50})	
In vitro	Antioxidant	Leaf	Ethanol	DPPH radical scavenging	96.29 µg (IC_{50})	Ravi et al. (2018)
		Leaf	Ethanol	NO radical scavenging	175.9 µg (IC_{50})	
		Leaf	Ethanol	OH radical scavenging	244.4 µg (IC_{50})	
		Leaf	Ethanol	Superoxide radical scavenging	474.32 µg (IC_{50})	

Level of scientific evidence	Bioactivity	Part	Extract / compound	Assay / model	Dose / concentration	Reference
		Leaf	Ethyl acetate	DPPH radical scavenging	327.9 µg (IC_{50})	
		Leaf	Ethyl acetate	Superoxide radical scavenging, NO radical scavenging, OH radical scavenging	0 µg (IC_{50})	
In vitro	Antioxidant	NS	Methanol	DPPH radical scavenging	67.23 µg/ml	Nanjian et al. (2015)

Abbreviations:

ABTS: 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonate); DPPH: 2,2-diphenyl-1-picrylhydrazyl; GI_{50}: Concentration for 50% of maximal inhibition of cell proliferation; IC_{50}: Half maximal inhibitory concentration; MIC: Minimum Inhibitory Concentration; NO: Nitric oxide; NS: Not stated; OH: Hydroxyl

3.2. In vivo bioactivities of I. aspalathoides

3.2.1. Anti-arthritic activity

Stem ethanol extract (250 mg/kg) was orally administered to complete Freund's adjuvant-induced arthritis in rats for 30 days. The results showed that there was a significant anti-arthritic activity. Also, there were changes in concentrations of superoxide dismutase, glutathione peroxidase, catalase, and lipid peroxide and kidney and liver functions (Rajkapoor et al., 2009).

3.2.2. Anticancer activity

An extract prepared using root and ethanol at a dose of 100 mg/kg a day was orally directed to N-nitrosodiethylamine-induced hepatocarcinogenesis in mice for three weeks. The outcomes exhibited that there were alterations in serum enzyme activities and protein concentrations. These alterations protected liver integrity and unveiled anticancer activity (Claimer et al., 2012).

3.2.3. Antidiabetic activity

Rajendran et al. (2013) studied the antidiabetic activity of the aqueous extract of the whole plant. A dose of 250mg/kg of the extract was orally administered to Streptozotocin-nicotinamide-induced diabetic rats. It was noticed that there was a regulation of glucose tolerance and a significant decrease in elevated blood glucose levels. Glibenclamide was used as a positive control in this research (Rajendran et al., 2013).

3.2.4. Antihepatotoxic activity

Stem ethanol extract was orally directed to carbon tetrachloride-induced hepatic damage in rats exhibited notable hepatoprotective properties (Rajkapoor et al., 2006).

3.2.5. Anti-inflammatory activity

Indigocarpan (125 mg/kg) was isolated from chloroform extract was administered to Carrageenan-induced rat paw oedema animal models showed anti-inflammatory effects. Ibuprofen was utilized as a positive control in this study (Selvam et al., 2004).

3.2.6. Immunomodulatory activity

Kaempferol 5-O-β-D-glucopyranoside isolated from aerial methanol extract and it was orally administered at a dose of 10 mg/kg to rats. The results showed that there was a remarkable elevation in antibody titers and percent neutrophil adhesion to nylon fibers and exhibited that kaempferol 5-O-β-D-glucopyranoside has significant immunomodulatory activity (Subramaniam Swarnalatha et al., 2015)

3.3. In vitro bioactivities of I. aspalathoides

3.3.1. Antibacterial activity

Ethanol extract of *I. aspalathoides* showed antibacterial effects at a minimum inhibitory concentration of 2.16 mg/ml in *Aeromonas hydrophila* assay (Bhuvaneswari & Balasundaram, 2006).

3.3.2. Anticancer activity

Balasubramanian et al. (2007) isolated 5,4'-dihydroxy 6,8-dimethoxy 7-O-rhamnosyl flavone from the stem and studied the anticancer properties in Ovarian cancer cell (OVCAR-5) assay. It has been observed anticancer effects at 4 μM of concentration for 50% of maximal inhibition of cell proliferation (Balasubramanian et al., 2007).

3.3.3. Antifungal activity

Ethanol extract prepared using leaves unveiled antifungal activities in *Aspergillus flavus, Aspergillus niger,* and *Aspergillus ochraceous* assays. However, the authors did not mention the concentrations used in this study (T. T. Kumar et al., 2018).

3.3.4. Anti-inflammatory activity

Indigocarpan isolated from this plant species revealed anti-inflammatory activity in the cyclooxygenase-1 inhibitory assay at a half-maximal inhibitory concentration (IC_{50}) of 30.5 μM (Selvam et al., 2004).

3.3.5. Antioxidant activity

Philips et al. (2010) researched the antioxidant effects of leaf chloroform extract. Antioxidant activity has been observed at IC_{50} 8.6 μg/ml in 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonate) radical scavenging assay (Philips et al., 2010).

3.4. Toxicity studies

There were a few studies conducted to study the toxicities of various *I. aspalathoides* extracts and isolated compounds. It has found that 2500 mg/kg of aqueous extract and 1000 mg/kg of kaempferol 5-O-β-D-glucopyranoside (for 14 days) were safe, and no harmful effects or mortality were observed (S. S. Kumar et al., 2010, 2012; Subramaniam Swarnalatha et al., 2015).

4. Conclusion

I. aspalathoides various extracts and isolated compounds exhibited several bioactivities. These studies provided scientific evidence for some of the ethno medicinal uses. Hence, it is recommended to conduct further bioactivity, and phytochemical researches to provide additional scientific evidence for the other ethno medicinal uses. This review analyzed, summarized, and documented the reported bioactivities of published publications. This review will be useful for further bioactivity and phytochemical studies using this plant species.

Conflict of interest

The authors declare that there is no conflict of interest.

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