

Mini review

Distribution, biosynthesis, laboratory synthesis, and therapeutic potential of derrone: A narrative review

Satyajit D. Sarker^{a,*}, Gamal M.M. Abdelfattah^b, Emran Habibi^a, Sirikanya Kaewpradit^a, Kenneth J. Ritchie^a, Lutfun Nahar^{a,b,**}

^a Centre for Natural Products Discovery (CNPD), School of Pharmacy and Biomolecular Sciences, Liverpool John Moores University, Byrom Street, Liverpool, L3 3AF, UK

^b Laboratory of Growth Regulators, Palacký University and Institute of Experimental Botany, The Czech Academy of Sciences, Šlechtitelů 27, Olomouc, 78371, Czech Republic

ARTICLE INFO

Keywords:

Derrone
Isoflavone
Bioactivity
Therapeutic potential
Biosynthesis
Synthesis
Distribution

ABSTRACT

Derrone is a naturally occurring pyranisoflavone, first isolated from the seeds of *Derris robusta* (Roxb. ex DC.) Benth. of the family Fabaceae, and subsequently reported from several additional species, predominantly within the Fabaceae and Moraceae families. This narrative review provides an overview of derrone, including its distribution across the plant kingdom, biosynthetic origin, laboratory synthesis, and documented bioactivities relevant to its potential therapeutic applications. Peer-reviewed publications on derrone published to date, excluding any doctoral theses or conference abstracts, were examined. Relevant information was obtained from various databases, including Web of Science, ScienceDirect, PubMed, and Google Scholar, using “derrone” as the sole keyword. Published studies have reported the antidiabetic, antifibrotic, antimicrobial, antiplatelet, antithrombotic, antitumour, cytotoxic/anticancer, hepatoprotective, and anti-HIV-1 properties of derrone, with the most therapeutically significant evidence relating to its anticancer, antidiabetic, antiplatelet, and antitumour properties. Nevertheless, further rigorous investigations are required to substantiate the therapeutic potential of derrone in human diseases.

1. Introduction

Derrone (m.p. 216–218 °C; molecular formula C₂₀H₁₆O₅; molecular weight 336.33804), IUPAC name 5-hydroxy-3-(4-hydroxyphenyl)-8,8-dimethyl-4H,8H-pyrano[2,3-f]chromen-4-one (Fig. 1), is a naturally occurring pyranisoflavone, first isolated almost half a century ago from the seeds of *Derris robusta* (Roxb. ex DC.) Benth. of the family Fabaceae (Chibber and Sharma, 1980; Chibber et al., 1981). However, the structure of this angular pyranisoflavone was confirmed by synthesis, showing the differences from its linear analogue (Tsukayama et al., 1992), and by re-isolation from *Retama raetam* flowers (Edziri et al., 2012). Since its first isolation, the focus of subsequent studies (Boiase et al., 2001; Máximo et al., 2002; Erasto et al., 2004; Darbour et al., 2007; Fedoreyev et al., 2008; Lee et al., 2009a; Lee et al., 2009b; Oh et al., 2009; Gomes et al., 2010; Jiang et al., 2010; Edziri et al., 2012; Yin et al., 2012; de Souza et al., 2013; Oyama et al., 2013; Muiva-Mutisya et al., 2014; Hoang et al., 2016; Kuang et al., 2017; Trinh et al., 2017;

Tsafack et al., 2017; Kang et al., 2019; Shin et al., 2021; Molagoda et al., 2023; Mouelle et al., 2025) has been on its bioactivity, laboratory synthesis, and re-isolation from new plant sources. However, these studies on derrone did not start immediately after its first isolation; it took over 20 years for further research on derrone to begin. The first reported UV absorption of derrone was mentioned as 280 nm (Chibber and Sharma, 1980), but later, more comprehensive data on the λ_{max} (MeOH) of this compound were reported: 266, 298, and 346 nm (Máximo et al., 2002), and 211, 268, 304 (sh) nm (Fedoreyev et al., 2008). In the first report of its isolation, only ¹H NMR data were reported (Chibber and Sharma, 1980), but later, comprehensive ¹H and ¹³C NMR data assignments based on extensive 1D and ²D NMR spectroscopic analyses were published (Máximo et al., 2002) (Table 1).

This narrative review includes publications on derrone published to date, except for any doctoral theses or conference abstracts. Relevant information was obtained from various databases, including Web of Science, ScienceDirect, PubMed, and Google Scholar. Derrone was used

* Corresponding author.

** Corresponding author at: Centre for Natural Products Discovery (CNPD), School of Pharmacy and Biomolecular Sciences, Liverpool John Moores University, Byrom Street, Liverpool L3 3AF, UK.

E-mail addresses: S.Sarker@ljmu.ac.uk (S.D. Sarker), L.Nahar@ljmu.ac.uk (L. Nahar).

<https://doi.org/10.1016/j.phytol.2026.104267>

Received 28 July 2026; Received in revised form 10 September 2026; Accepted 24 September 2026

Available online 28 September 2026

1874-3900/© 2026 The Author(s). Published by Elsevier Ltd on behalf of Phytochemical Society of Europe. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

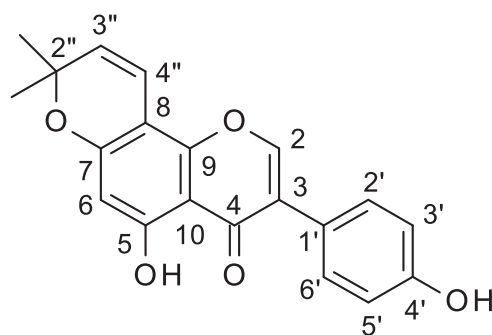


Fig. 1. Chemical structure of derrone.

Table 1
¹H and ¹³C NMR data (in CDCl₃) of derrone.

Position	¹ H NMR		¹³ C NMR
	Chemical shift δ in ppm, coupling constant J in Hz in parentheses		Chemical shift δ in ppm
	90 Hz (Chibber and Sharma, 1980)	400 Hz (Máximo et al., 2002)	100 Hz (Máximo et al., 2002)
2	7.73 s, 1 H	7.88 s, 1 H	152.6
3	-	-	123.7
4	-	-	181.2
5	-	-	162.5
5-OH	13.80 s, 1 H	12.90 s, 1 H	-
6	6.27 s, 1 H	6.30 s, 1 H	100.4
7	-	-	159.8
8	-	-	101.2
9	-	-	152.6
10	-	-	106.1
1'	-	-	123.1
2' and 6'	7.29 d, 2 H (9.0)	7.40 s, 1 H (8.0)	130.5
3' and 5'	6.77 d, 2 H (9.0)	6.87 s, 1 H (8.4)	115.7
4'	-	-	156.1
2''	-	-	78.1
3''	5.56 d, 1 H (10.0)	5.90 d, 1 H (10.0)	127.6
4''	6.68 d, 1 H (10.0)	6.83 s, 1 H (10.0)	114.7
2''-Me (x 2)	1.42 s, 6 H	1.47 s, 6 H	28.1

as the only keyword in the search. This review provides an overview of derrone, including its distribution in the plant kingdom, biosynthesis, laboratory synthesis, and reported bioactivities in relation to its potential therapeutic applications.

2. Distribution

Although derrone (Fig. 1) was first reported in 1980 (Chibber and Sharma, 1980), Máximo et al. (2002) later reisolated the compound from the aerial parts of *Ulex jussiae* Webb. and probably mistakenly described it as a new prenylisoflavone. The distribution of derrone in the plant kingdom is largely confined to two major families, Fabaceae Lindl. and Moraceae Gaudich. (Table 2), but this compound was also found in one species each from the families Asteraceae Bercht. and J. Presl (Gomes et al., 2010) and Dilleniaceae Salisb (Lee et al., 2009b).

Within the Fabaceae, derrone has been isolated from 10 genera: *Bolusanthus* Harms., *Derris* Lour., *Desmodium* Desv., *Erythrina* L., *Glycyrrhiza* L., *Maackia* Rupr., *Retama* Raf., *Tephrosia* Pers., *Ulex* L., and *Vatairea* Aubl. In the Moraceae, it has been reported from the genera *Cudrania* Carrière, *Ficus* L., and *Maclura* Nutt. (Table 2). The genus *Ficus* appears to be a major source of derrone, with at least four species, *Ficus microcarpa*, *F. nymphaeolia*, *F. racemosa*, and *F. sur*, known to produce this pyranoisoflavone (Darbour et al., 2007; Jiang et al., 2010; Trinh et al., 2017; Mouelle et al., 2025).

Table 2

Distribution of derrone in the plant kingdom.

Plant species	Family	Plant part	References
<i>Blainvillea rhomboidea</i> Cass.	Asteraceae	Aerial parts	Gomes et al. (2010)
<i>Bolusanthus speciosus</i> (Bolus) Harms	Fabaceae	Stem bark	Boiase et al. (2001)
<i>Cudrania tricuspidata</i> (Carrière) Bureau	Moraceae	Roots	Erasto et al., (2004)
		Suspension culture	Yin et al. (2012)
		Unripe fruits	Kang et al., (2019); Shin et al., (2021)
		Leaves	Molagoda et al. (2023)
<i>Derris robusta</i> (Roxb. ex DC.) Benth.	Fabaceae	Seeds	Chibber and Sharma (1980); Chibber et al. (1981)
<i>Desmodium uncinatum</i> (Jacq.) DC	Fabaceae	Aerial parts	Tsafack et al. (2017)
<i>Erythrina senegalensis</i> DC.	Fabaceae	Stem bark	Oh et al., (2009); Lee et al., (2009a)
<i>Erythrina orientalis</i> L. Murr.	Fabaceae	Stem bark	Hoang et al. (2016)
<i>Ficus microcarpa</i> L.f.	Moraceae	Roots	Jiang et al. (2010)
<i>Ficus nymphaeolia</i> Mill.	Moraceae	Stem bark	Darbour et al. (2007)
<i>Ficus racemosa</i> L.	Moraceae	Aerial parts	Trinh et al. (2017)
<i>Ficus sur</i> Forssk	Moraceae	Aerial parts	Mouelle et al., (2025)
<i>Glycyrrhiza glabra</i> L.	Fabaceae	Roots	Kuang et al. (2017)
<i>Maackia amurensis</i> Rupr.	Fabaceae	Callus culture	Fedeoreyev et al. (2008)
<i>Maclura tinctoria</i> (L.) Steud.	Moraceae	Fruits	Oyama et al. (2013)
<i>Retama raetam</i> (Forssk.) Webb & Berthel	Fabaceae	Flowers	Edziri et al., (2012)
<i>Tephrosia purpurea</i> (L.) Pers.	Fabaceae	Roots	Muiva-Mutisya et al. (2014)
<i>Tetracera scandens</i> (L.) Merr.	Dilleniaceae	Aerial parts	Lee et al. (2009b)
<i>Ulex jussiae</i> Webb	Fabaceae	Aerial parts	Máximo et al., (2002)
<i>Vatairea guianensis</i> Aubl	Fabaceae	Leaves	de Souza et al. (2013)

3. Biosynthesis

Biosynthesis of isoflavones, predominantly found in the plants of the family Fabaceae, e.g., soybeans, follows the phenylpropanoid pathway, starting from the amino acid phenylalanine or tyrosine (Aoki et al., 2000; Veitch, 2013; Wang et al., 2024) (Fig. 2). The biosynthetic process relies on a sequence of enzymatic reactions to shift the aromatic B-ring, producing distinct structural backbones. The enzyme phenylalanine ammonia-lyase drives the deamination of phenylalanine into cinnamic acid, which undergoes hydroxylation governed by cinnamate 4-hydroxylase to produce 4-coumaric acid. 4-Coumarate CoA-ligase converts 4-coumaric acid to 4-coumaroyl-CoA. The enzyme chalcone synthase condenses 4-coumaroyl-CoA with malonyl-CoA to yield isoliquiritigenin (or naringenin). The chalcones are transformed into flavanone/isoflavone precursors, liquiritigenin or naringenin, by chalcone isomerase. The enzyme isoflavone synthase provides the metabolic entry point for isoflavonoids; it catalyzes aryl ring migration and hydroxylation on the flavanones to produce 2-hydroxyisoflavanone, which undergoes dehydration by 2-hydroxyisoflavanone dehydratase to generate other isoflavones like daidzein or genistein (Fig. 2). Core isoflavones undergo specific enzyme-mediated further modifications, including glycosylation, methylation, and prenylation, governed by isoflavone uridine-diphosphate-glucosyltransferases, O-methyltransferases, and prenyltransferases. Prenylated isoflavones enzymatically form furano- or pyrano-isoflavone like derrone through additional furan or pyran ring formation from the prenyl functionality, catalyzed by pyran synthase or cyclase.

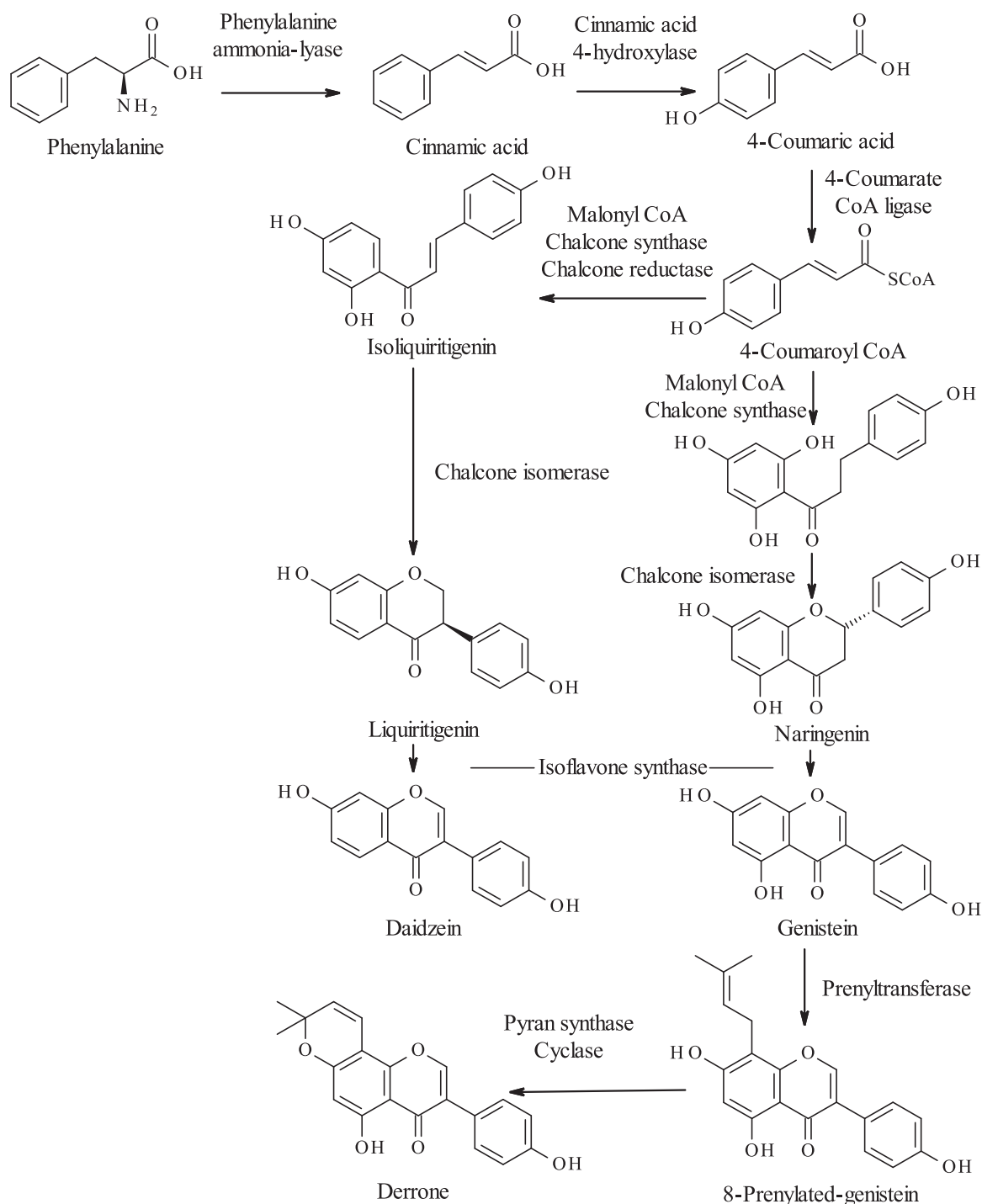


Fig. 2. Plausible biosynthetic pathway for derrone.

4. Laboratory synthesis

The chemical synthesis of derrone was first reported by Rao et al. (1987). A reaction between phenacylchroman and ethoxyalyl chloride in pyridine (C_5H_5N), followed by hydrolysis of the resulting ester and decarboxylation of the acid, gave a dihydro-4-O-methyl alpinum pyranoisoflavone, which was demethylated to dihydroderrone. Dihydroderrone was cyclodehydrogenated to yield derrone (Fig. 3). In general, the isoflavone core skeleton can be synthesized from phloroglucinol using the Suzuki-Miyaura cross-coupling reaction (Meringdal and Menche, 2025), and the 2,2-dimethylpyran ring on the isoflavone

core can be introduced using C-prenylation followed by an oxidation or cyclization reaction, often with DDQ, to achieve the double bond in the pyran ring (Luan et al., 2024). Derrone can also be semisynthesized through simple modification of structurally related natural isoflavones, e.g., selective demethylation of 4'-O-methylderrone.

5. Therapeutic potential

Derrone (Fig. 1) belongs to the pyranoisoflavone or prenylated isoflavone group of naturally occurring phenolic compounds. Isoflavones possess several bioactivities and health benefits, particularly in their role

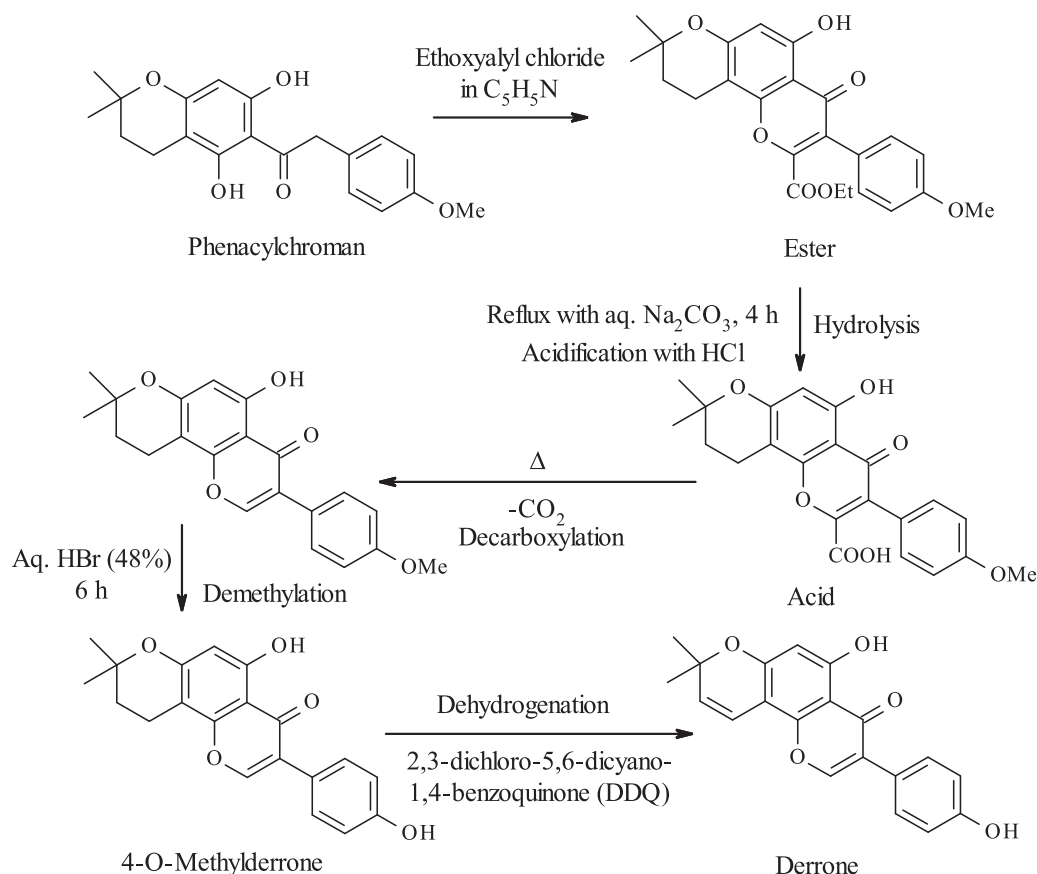


Fig. 3. Laboratory synthesis of derrone (Rao et al., 1987).

in immunomodulation, cognition, and the prevention of cancer, cardiovascular, and skin diseases, as well as osteoporosis and obesity, and in managing menopausal symptoms (Setchell and Cassidy, 1999; Mladokova, 2009; Gomez-Zorita et al., 2020; Hsiao et al., 2020; Kim, 2021; Nahar et al., 2026). Since its isolation, several bioactivity studies on derrone have been performed, demonstrating its antibacterial (Erasto et al., 2004; Edziri et al., 2012), antifibrotic (Molagoda et al., 2023), antifungal (Máximo et al., 2002; Erasto et al., 2004; Edziri et al., 2012), antiplatelet or antithrombotic (Shin et al., 2021), antitumour (Hoang et al., 2016), aurora kinase inhibitory (Hoang et al., 2016; Kang et al., 2019), diacylglycerol acyltransferase (DGAT)-inhibitory (Oh et al., 2009), glucose uptake stimulating (Lee et al., 2009b; Trinh et al., 2017), hepatoprotective (Kuang et al., 2017) and HIV-1 protease-inhibitory (Lee et al., 2009a) activities (Table 3). All these bioactivities of derrone are discussed in the following sub-sections.

5.1. Antibacterial activity

The antibacterial activity of derrone was first reported in 2004 (Erasto et al., 2004), where this pyranoisoflavone, isolated from *Bolusanthus speciosus*, was shown to inhibit the growth of *E. coli*, *B. subtilis*, and *S. aureus* at minimum doses of 100, 20, and 0.1 μ g, respectively. A bioautographic thin-layer chromatographic (TLC) assay (Rahalison et al., 1991) was used in that study. A few years later, Edziri et al. (2012) used disc diffusion (Bauer et al., 1966; Balouiri et al., 2015) and micro-well-dilution (Balouiri et al., 2015; Geaman et al., 2024) assays to establish the antibacterial activity of derrone (50 μ g/disc), purified from *R. raetam* flowers, against *E. faecalis* (zone of inhibition = 17 mm), *E. coli* (zone of inhibition = 19 mm), and *P. aeruginosa* (zone of inhibition = 16 mm); the minimum inhibitory concentrations were 100

μ g/mL, 7.81 μ g/mL, and 15.62 μ g/mL, respectively. The standard antibiotics, gentamycin and ofloxacin, were used as positive controls in disc diffusion and micro-well-dilution assays, respectively.

5.2. Antifibrotic activity

3-[4,5-Dimethylthiazol-2-yl]-2,5 diphenyl tetrazolium bromide (MTT) cell viability assay (Mosmann, 1983) using human MRC-5 lung fibroblasts, Western blotting (Burnette, 1981), Sircol collagen assays (Lareu et al., 2010), and *in silico* screening (Sarker and Nahar, 2024) were performed with derrone, isolated from *Cudrania tricuspidata*, to demonstrate its antifibrotic activity (Molagoda et al., 2023). Derrone promoted antifibrotic effects on TGF (transforming growth factor)- β 1-stimulated MRC-5 lung fibroblast cells and bleomycin-induced lung fibrosis, mediated through the reduction of TGF- β 1-induced myofibroblast differentiation by inhibiting the T β RI-mediated Smad2/3 signaling pathway. It can be noted that TGF- β 1, an important fibrogenic cytokine, promotes fibroblast activation and differentiation to myofibroblasts, and ECM (extracellular matrix) component deposition by binding to the T β RII dimer, and contributes to airway wall thickness and obstruction (Hayashi and Sakai, 2012; Molagoda et al., 2023). High concentrations of derrone increased cytotoxicity towards MRC-5 cells after long-term use, but at low concentrations (<0.05 μ g/mL), this compound did not cause any considerable cell death over a three-day treatment. A significant decrease in the expression of TGF- β 1, fibronectin, elastin, and collagen1 α 1, accompanied by downregulation of α -SMA expression in TGF- β 1-stimulated MRC-5 cells, was observed with derrone-treatment. Derrone supplementation remarkably reduced the histological deformations, e.g., severe fibrotic histopathological changes in infiltration, alveolar congestion, and alveolar wall thickness, in bleomycin-treated mice. *In silico* studies, e.g., molecular docking, showed derrone fitting

Table 3
Bioactivities of derrone.

Bioactivity	Assessment method	Outcome	References
Antibacterial activity	Bioautographic thin-layer chromatographic (TLC) assay	Derrone at the minimum doses of 100, 20, and 0.10 µg inhibited the growth of <i>Escherichia coli</i> , <i>Bacillus subtilis</i> , and <i>Staphylococcus aureus</i> , respectively.	Erasto et al., (2004)
	Disc diffusion and micro-well-dilution assays	Active against <i>Enterococcus faecalis</i> , <i>E. coli</i> , and <i>Pseudomonas aeruginosa</i> (7.81–15.62 µg/mL).	Edziri et al., (2012)
Antifibrotic activity	MTT cell viability assay using human MRC-5 lung fibroblasts, Western blotting assay, Sircol collagen assay, and <i>in silico</i> screening	Promoted antifibrotic effects on TGF-β1-stimulated MRC-5 lung fibroblast cells and bleomycin-induced lung fibrosis, mediated through the reduction of TGF-β1-induced myofibroblast differentiation by inhibiting the TβRI-mediated Smad2/3 signaling pathway.	Molagoda et al., (2023)
Antifungal activity	Bioautographic thin-layer chromatographic (TLC) assay	Tested against <i>Cladosporium cucumerinum</i> , but no noticeable antifungal activity was detected at test concentrations.	Máximo et al., (2002)
	Bioautographic thin-layer chromatographic (TLC) assay	Tested against <i>Candida mycoderma</i> , and derrone (minimum inhibitory dose = 1 µg) inhibited the growth.	Erasto et al., (2004)
	Disc diffusion and micro-well-dilution assays	Strong antifungal activity against <i>Candida</i> species (MIC 7.81 µg/mL).	Edziri et al., (2012)
Antithrombotic activity/ Antiplatelet activity	A battery of <i>in vitro</i> antiplatelet assays	Inhibited platelet aggregation, granule secretion, thromboxane A ₂ generation, and clot retraction.	Shin et al., (2021)
Antitumour activity	Multicellular tumour spheroid (MCTS) culture assay using MCF7 cell line	Derrone inhibited the formation and growth of MCF7 multicellular tumour spheroids.	Hoang et al., (2016)
	Protein kinase assay	Inhibited aurora kinase domain (80%) at the concentration of 60 µM and displayed higher activity against aurora B than against aurora kinase A, with IC ₅₀ values of 6 and 22.3 µM, respectively.	Hoang et al., (2016)

Table 3 (continued)

Bioactivity	Assessment method	Outcome	References
Cytotoxicity/ anticancer potential	MTT [3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyl tetrazolium bromide] assay using Hep-2 cells	Shown cytotoxicity with an IC ₅₀ value of 30 µg/mL.	Edziri et al., (2012)
	MTT assay using HeLa, MCF7, H1299, and KPL4 cell lines	Cytotoxic to all four cancer cell lines, with the most potent activity against MCF7 (IC ₅₀ = 24.4 ± 3.9 µM) and H1299 cells (IC ₅₀ = 31.2 ± 8.3 µM).	Hoang et al., (2016)
Diacylglycerol acyltransferase (DGAT)-inhibitory activity	MTT assay using the A549 cell line, immunoblotting, analysis of cell cycle, flow cytometric detection of ROS, and caspase activity assay.	Induced autophagic cell death through the induction of reactive oxygen species (ROS) and ERK (extracellular signal-regulated kinase) in A549 adenocarcinoma cells.	Kang et al., (2019)
	<i>In vitro</i> DGAT inhibitory assay	Derrone inhibited DGAT (IC ₅₀ = 15.1 ± 1.1 µg/mL). Enzyme reactions were conducted at 37 °C for 10 min in the presence of 100 mM MgCl ₂ .	Oh et al., (2009)
Glucose uptake- stimulating activity	Glucose uptake assay, PTP1B (protein-tyrosine phosphatase 1B) inhibition assay, western blot analysis, RT-PCR (reverse transcription-polymerase chain reaction), and cell viability assay	Derrone stimulated glucose uptake, AMPK (adenosine monophosphate-activated kinase) phosphorylation, GLUT4 (glucose transport protein 4) and GLUT1 (glucose transport protein 1) mRNA expressions, and PTP1B (protein tyrosine phosphatase 1B) inhibition in L6 myotubes.	Lee et al., (2009b)
	PTP1B inhibition assay	Competitively inhibited PTP1B with an IC ₅₀ value of 12.6 ± 1.6 µM.	Trinh et al., (2017)
Hepatoprotective activity	Cell viability assay using APAP (acetaminophen)-treated HepG2 cells.	Exhibited protective effects against APAP to improve cell viability > 80%.	Kuang et al., (2017)
Human Immunodeficiency Virus 1 (HIV-1)- protease inhibitory activity	An HPLC method using a synthetic heptapeptide [His-Lys-Ala-Arg-Val-Leu-(pNO ₂ -Phe)-Glu-Ala-Nle-Ser-NH ₂] as a substrate.	Dose-dependent inhibitory activity on HIV-1 protease with an IC ₅₀ value of 18.2 ± 0.2 µM.	Lee et al., (2009a)

well into the ATP (adenosine triphosphate)-binding pocket of the TGF-β receptor type 1 kinase domain with stronger binding scores than ATP. It was also found that derrone inhibited TGF-β1-induced phosphorylation and nuclear translocations of Smad2/3. These findings revealed the therapeutic potential of derrone as an antifibrotic agent preventing pulmonary fibrosis.

5.3. Antifungal activity

Three reports have been published on the antifungal properties of derrone (Máximo et al., 2002; Erasto et al., 2004; Edziri et al., 2012). Two of these studies (Máximo et al., 2002; Erasto et al., 2004) used a bioautographic thin-layer chromatographic (TLC) assay, while the third study used a combination of disc diffusion and micro-well-dilution assays (Edziri et al., 2012). Máximo et al. (2002) tested derrone, isolated from the aerial parts of *Ulex jussiae*, against the plant pathogenic fungal strain *Cladosporium cucumerinum*, but no noticeable antifungal activity was detected at test concentrations. However, the antifungal activity of this compound was evident against *Candida* species (Erasto et al., 2004; Edziri et al., 2012). Derrone, isolated from the root wood of *Bolusanthus speciosus*, inhibited the growth of *Candida mycoderma* at a minimum inhibitory dose of 1 µg (Erasto et al., 2004). Antifungal drug miconazole was used as the positive control, and the minimum inhibitory dose was 0.0001 µg. Edziri et al. (2012) assessed the antifungal potential of derrone, isolated from the flowers of *R. raetam*, against four *Candida* species, *C. albicans*, *C. glabrata*, *C. kreusei*, and *C. parapsilosis*, and found a strong antifungal activity against all tested *Candida* species with an MIC value of 7.81 µg/mL, while the MIC value of the positive control, amphotericin, was 0.5 µg/mL. In the disc diffusion assay, derrone (50 µg/disc) showed a zone of inhibition of 25 mm against all four fungal strains (zone of inhibition of amphotericin at 100 µg/disc = 19 mm). Although the antifungal activity of derrone against *Candida* species appears promising, further studies, particularly those aimed at establishing its mode of action and toxicity, are needed to demonstrate the antifungal therapeutic potential of derrone.

5.4. Antithrombotic activity/antiplatelet activity

In circulating blood, platelets play a vital role in hemostasis, the process that stops bleeding at sites of vascular injury while maintaining blood in a fluid state elsewhere, and in thrombosis, the formation of intravascular clots that obstruct blood flow (Shin et al., 2021). Because platelets are key mediators of thrombus formation, their activation and aggregation can adversely influence the development and progression of cardiovascular diseases. Thus, the inhibition of platelet aggregation can be used as a tool for managing cardiovascular health by preventing the formation of blood clots. Several natural products have been implicated in antiplatelet or antithrombotic activity (Hirsch et al., 2017). Derrone, isolated from *Cudrania tricuspidata*, was found to inhibit collagen-stimulated platelet aggregation, granule secretion, thromboxane A₂ generation, and clot retraction (Shin et al., 2021). Several *in vitro* assays, including platelet aggregation analysis, cytotoxicity testing, intracellular calcium level estimation, detection of thromboxane B₂ and serotonin, immunoblotting, fibrinogen binding and adhesion assay, and assessment of fibrin clot retraction, were performed to establish this activity. It was shown that the inhibition of collagen-stimulated platelet aggregation by derrone, mediated through the downregulation of intracellular calcium concentration, αIIb/β₃ affinity, and clot retraction, was accomplished by the regulation of IP₃RI (Ser¹⁷⁵⁶), VASP (Ser¹⁵⁷ and Ser²³⁹), cPLA₂ (Ser⁵⁰⁵), and p38^{MAPK} (Shin et al., 2021). It can be noted that IP₃RI refers to the type 1 inositol 1,4,5-trisphosphate receptor, which is an intracellular calcium release channel found on the membrane of the endoplasmic reticulum, and VASP stands for the vasodilator-stimulated phosphoprotein, which is a key actin-regulatory protein whose activity is primarily governed by site-specific phosphorylation at Ser¹⁵⁷ and Ser²³⁹ by cyclic nucleotide-dependent kinases. Derrone was also found to increase the key antiplatelet mediators, cyclic nucleotides cAMP and cGMP levels in human platelets. All these findings support the antiplatelet property of the crude extracts of *C. tricuspidata* (Ro and Cho, 2019) and suggest that derrone could be an ideal candidate for antiplatelet or antithrombotic drug development.

5.5. Antitumour activity

Derrone, isolated from the stem bark of *Erythrina orientalis*, showed antitumour activity by inhibiting the formation and growth of MCF7 multicellular tumour spheroids (MCTS) at concentrations of 15, 30, and 60 µM (Hoang et al., 2016). MCTS culture assay employing the MCF7 cell line, which is known to have a profound ability to produce spheroids when using the hanging drop method (Kelm et al., 2003), was used in this study. It was found that at a concentration of 15 µM, spheroids were formed, but growth was much slower than that of the control (Hoang et al., 2016). The tumour inhibitory activity of derrone was established by adding derrone onto the MCF7 spheroids on day 3 of culture on an agarose-coated plate at two concentrations, 30 and 60 µM, revealing a significant decrease in the size of the spheroids treated with derrone compared to those treated with the control. Derrone also brought about morphological changes in the spheroids; some cells of the outer layer, the highest proliferated part in the spheroid structure, became loose and started to die after 7 days. After 15 days of treatment, the MCF7 tumour spheroid growth was 17.5% and 65.4%, respectively, at 30 and 60 µM of derrone. This study demonstrated the effectiveness of derrone in inhibiting the formation and suppression of the growth of MCF7 tumour spheroids.

Aurora kinases are a group of highly conserved serine/threonine kinases that are essential for accurate cell division; they regulate principal mitotic processes, including centrosome duplication, spindle assembly, and chromosome segregation (Willems et al., 2018). These enzymes are overexpressed in human cancers, making them prime targets for cancer therapies. Thus, aurora kinase inhibitors are considered potential anticancer/antitumour agents, as the inhibition of these enzymes results in mitotic arrest, polyploidy, or apoptosis, causing starvation of rapidly dividing solid and haematological tumours. Several natural products possess aurora kinase inhibitory activities (Jung et al., 2015). Derrone, isolated from *E. orientalis*, was shown to inhibit the aurora kinase domain (80%) at the concentration of 60 µM using a xCELLigence System and displayed higher activity against aurora B than against aurora kinase A, with IC₅₀ values of 6 µM and 22.3 µM, respectively (Hoang et al., 2016). MCF7 and H1299 cells were used to characterize derrone as an aurora B inhibitor. These findings suggest that derrone has therapeutic potential against tumours.

5.6. Cytotoxicity/anticancer potential

The cytotoxicity of compounds against cancer cell lines is often considered to be an indicator of their potential anticancer properties. However, not all cytotoxic compounds are anticancer agents. There is a large body of research published in the literature documenting the cytotoxic potential of natural products, and describing how some of these cytotoxic compounds, e.g., Taxol and vincristine, were developed as successful anticancer drugs (Sarker et al., 2020). Edziri et al. (2012) conducted an MTT assay with derrone using Hep-2 cells (laryngeal carcinoma cells), and found that derrone, isolated from *R. raetam* flowers, was moderately cytotoxic to Hep-2 cells with an IC₅₀ value of 30 µg/mL. Similarly, this compound showed cytotoxicity against four cancer cell lines, including HeLa (immortalized cervical cells), MCF7 (breast cancer), H1299 (aggressive human non-small cell lung carcinoma cells), and KPL4 (breast cancer) cell lines, in the MTT assay (Hoang et al., 2016). While derrone was found to be active against all four cell lines, the most potent activity was observed against MCF7 (IC₅₀ = 24.4 ± 3.9 µM) and H1299 cells (IC₅₀ = 31.2 ± 8.3 µM). A combination of MTT assay using the A549 (lung cancer) cell line, immunoblotting, analysis of cell cycle, flow cytometric detection of reactive oxygen species (ROS), and caspase activity assay revealed the anticancer potential of derrone (Kang et al., 2019). Derrone, isolated from the unripe fruits of *C. tricuspidata*, induced autophagic cell death through the induction of ROS and ERK (extracellular signal-regulated kinase) in A549 adenocarcinoma cells. The A549 cell death by derrone was

associated with apoptosis, at least partially (Kang et al., 2019).

5.7. Diacylglycerol acyltransferase (DGAT)-inhibitory activity

Inhibition of diacylglycerol acyltransferase (DGAT), the enzyme responsible for the final step of triglyceride synthesis, prevents the body from storing excess dietary fat, making DGAT inhibitors a therapeutic target for metabolic conditions like obesity, type 2 diabetes, and fatty liver disease (Chen et al., 2022). A DGAT-inhibitory *in vitro* assay (Coleman, 1992) was conducted with derrone, isolated from the stem bark of *Erythrina senegalensis* (Oh et al., 2009). Derrone inhibited DGAT with an IC_{50} value of 15.1 ± 1.1 $\mu\text{g/mL}$ compared to that of the positive control, kurarinone ($IC_{50} = 4.8$ $\mu\text{g/mL}$). Enzyme reactions were conducted at 37°C for 10 min in the presence of 100 mM MgCl_2 . The finding in this study is promising as it revealed the potential of derrone as a DGAT inhibitor and naturally occurring other isoflavones as a new class of DGAT inhibitors. However, further investigations and optimisation are necessary to establish the therapeutic potential of derrone and other isoflavones in managing obesity, type 2 diabetes, and insulin resistance.

5.8. Glucose uptake-stimulating activity

Glucose uptake-stimulating activity is associated with the biological processes and pathways that drive glucose from the bloodstream into cells, primarily for energy or storage. This activity is generally mediated by insulin, muscle contraction (exercise), and cellular energy sensors, which trigger the movement of GLUT4 transporters to the cell membrane (Richter et al., 2001). Several natural products, e.g., berberine, kaempferol, quercetin, and resveratrol, are known to stimulate glucose uptake and manage type 2 diabetes (Sknepnek et al., 2025; Vong et al., 2025; Swati et al., 2026). Derrone, purified from the aerial parts of *Tetracera scandens*, was found to stimulate glucose uptake (at a 25 μM concentration, a 177 and 285.7% increase), AMPK (adenosine monophosphate-activated kinase) phosphorylation, GLUT4 (glucose transport protein 4) and GLUT1 (glucose transport protein 1) mRNA expressions, and PTP1B (protein tyrosine phosphatase 1B) inhibition in L6 myotubes (Lee et al., 2009b). AMPK was significantly phosphorylated after the cells were treated with derrone at a 10 μM concentration, suggesting its involvement in the enhanced glucose uptake induced by derrone. To investigate whether the difference in expression of GLUT4 and GLUT1 took place at the level of transcription, an RT-PCR assay was used; the treatment of L6 myotubes with derrone increased the GLUT4 mRNA levels by 1.92-fold, and the GLUT1 mRNA levels by 1.74-fold (Lee et al., 2009b). Derrone displayed a moderate level of PTP1B inhibition with an IC_{50} value of 37.52 ± 0.31 μM . Trinh et al. (2017) also demonstrated that derrone, isolated from the aerial parts of *Ficus racemosa*, competitively inhibited PTP1B with an IC_{50} value of 12.6 ± 1.6 μM . All these studies provide evidence that derrone could be a candidate for a novel therapeutic strategy for type 2 diabetes treatment, but obviously, further studies are necessary to clarify the molecular mechanism and assess its toxicity.

5.9. Hepatoprotective activity

A cell viability assay was conducted on derrone, isolated from the roots of *Glycyrrhiza glabra*, using acetaminophen (14 mM)-treated HepG2 (human liver cancer) cells (Kuang et al., 2017). It was found that derrone exhibited protective effects against acetaminophen-induced hepatic toxicity by improving cell viability to $> 80\%$. As derrone has phenolic hydroxyl groups in its structure, like several other isoflavones, it possesses inherent antioxidative properties (Arora et al., 1998; Rufer and Kulling, 2006), which may be responsible for its hepatoprotective properties. However, the available data are not enough to establish its therapeutic potential as a hepatoprotective agent.

5.10. HIV-1 protease inhibitory activity

Derrone, purified from the stem bark of the Cameroonian medicinal plant *Erythrina senegalensis*, showed dose-dependent inhibitory activity on HIV-1 protease with an IC_{50} value of 18.2 ± 0.2 μM (Lee et al., 2009a). An HPLC assay method (Lee et al., 2008a; Lee et al., 2008b) was employed to assess anti-HIV-1 protease inhibition using a synthetic heptapeptide [His-Lys-Ala-Arg-Val-Leu-(pNO₂-Phe)-Glu-Ala-Nle-Ser-NH₂] as a substrate. HIV-1 encodes a set of proteins, including protease and reverse transcriptase, that are involved in the viral replication cycle. Inhibition of viral replication and the inhibition of different steps in its life cycle, including adsorption, fusion, reverse transcription, integration, transcription, maturation, and budding, are considered promising approaches in anti-HIV drug development. Thus, the inhibitors of HIV-1 protease and reverse transcriptase can be developed as potential anti-HIV-1 therapeutic agents, and derrone has that potential.

6. Conclusion

Derrone is distributed mainly across species in the Fabaceae and Moraceae families, with the genus *Ficus* emerging as the most extensively investigated botanical source of this pyranoisoflavone. Phenacylchroman could be used as the starting material for the total synthesis of derrone, although semisynthetic approaches, such as selective demethylation of 4'-O-methylderrone, remain feasible alternatives. Derrone exhibits a broad pharmacological profile, including antidiabetic, antifibrotic, antimicrobial, antiplatelet, antithrombotic, anti-tumour, cytotoxic/anticancer, hepatoprotective, and anti-HIV-1 activities. Among these, its anticancer, antidiabetic, antiplatelet, and antitumour effects appear most therapeutically promising. Nonetheless, more rigorous mechanistic and translational studies are required before the bioactive potential of derrone can be effectively applied in clinical contexts.

CRedit authorship contribution statement

Satyajit D. Sarker: Writing – review & editing, Writing – original draft, Software, Resources, Methodology, Formal analysis, Conceptualization. **Gamal M.M. Abdelfattah:** Writing – original draft, Data curation, Conceptualization. **Emran Habibi:** Writing – original draft, Methodology, Data curation, Conceptualization. **Sirikanya Kaewpradit:** Writing – original draft, Data curation, Conceptualization. **Kenneth J. Ritchie:** Writing – review & editing, Writing – original draft, Resources, Methodology, Formal analysis, Data curation, Conceptualization. **Lutfun Nahar:** Writing – review & editing, Writing – original draft, Supervision, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

We declare **no conflicts of interest**.

Data availability

It is review article, and it has only included published data.

References

- Aoki, T., Akashi, T., Ayabe, S., 2000. Flavonoids of leguminous plants: Structure, biological activity, and biosynthesis. *J. Plant. Res.* 113, 475–488.
- Arora, A., Nair, M.G., Strasburg, G.M., 1998. Antioxidant activities of isoflavones and their biological metabolites in a liposomal system. *Arch. Biochem. Biophys.* 356 (2), 133–141.
- Blouiri, M., Sadiki, M., Ibnsouda, S.K., 2015. Methods for *in vitro* evaluating antimicrobial activity: A review. *J. Pharm. Anal.* 6 (2), 71–79.
- Bauer, A.W., Kirby, W.M.M., Sherris, J.C., et al., 1966. Antibiotic susceptibility testing by a standardized single disk method. *Am. J. Clin. Pathol.* 45 (4), 493–496.

- Boiaise, G., Wanjala, C.C.W., Majinda, R.R.T., 2001. Two new isoflavonoids from *Bolusanthus speciosus*. *Bull. Chem. Soc. Ethiop.* 15 (2), 131–136.
- Burnette, W.N., 1981. "Western blotting": electrophoretic transfer of proteins from sodium dodecyl sulfate-polyacrylamide gels to unmodified nitrocellulose and radiographic detection with antibody and radioiodinated protein A. *Anal. Biochem.* 112 (2), 195–203.
- Chen, G., Harwood, J.L., Lemieux, M.J., et al., 2022. Acyl-CoA:diacylglycerol acyltransferase: Properties, physiological roles, metabolic engineering and intentional control. *Prog. Lipid Res.* 88, 101181.
- Chibber, S.S., Sharma, R.P., 1980. Derrone, a new pyranisoflavone from *Derris robusta* seeds. *Phytochemistry* 19, 1857–1858.
- Chibber, S.S., Sharma, R.P., Dutt, S.K., 1981. Derrone-4'-O-methyl ether from seeds of *Derris robusta*. *Curr. Sci.* 50, 818–819.
- Coleman, R.A., 1992. Diacylglycerol acyltransferase and monoacylglycerol acyltransferase from liver and intestine. *Methods Enzymol.* 209, 98–103.
- Darbour, N., Bayet, C., Rodin-Bercion, S., et al., 2007. Isoflavones from *Ficus nymphaeifolia*. *Nat. Prod. Res.* 21 (5), 461–464.
- de Souza, R.F., Marinho, V.H.S., da Silva, G.A., et al., 2013. New isoflavones from the leaves of *Vatairea guianensis* Auble. *J. Braz. Chem. Soc.* 24 (11), 1857–1863.
- Edziri, H., Mastouri, M., Mahjoub, M.A., et al., 2012. Antibacterial, antifungal and cytotoxic activities of two flavonoids from *Retama raetam* flowers. *Molecules* 17 (6), 7284–7293.
- Erasto, P., Bojase-Moleta, G., Majinda, R.R.T., 2004. Antimicrobial and antioxidant flavonoids from the root wood of *Bolusanthus speciosus*. *Phytochemistry* 65 (7), 875–880.
- Fedeoreyev, S.A., Bulgakov, V.P., Grishchenko, O.V., et al., 2008. Isoflavonoid composition of a callus culture of the relict tree *Maackia amurensis* Rupr. et Maxim. *J. Agric. Food Chem.* 56 (16), 7023–7031.
- Geaman, W., Choi, B.I., Kaindl, J., et al., 2024. Microbroth dilution method for antibiotic susceptibility testing of fastidious and anaerobic bacteria of the urinary microbiome. *Microbiol. Spectr.* 12 (6), e00314–e00324.
- Gomes, R.F., dos Santos, H.S., Albuquerque, M.R.J.R., et al., 2010. *Blainvillea rhomboidea*: Chemical constituents and cytotoxic activity. *Quim. Nova* 33 (5), 1122–1125.
- Gomez-Zorita, S., Gonzalez-Arceo, M., Fernandez-Quintela, A., et al., 2020. Scientific evidence supporting the beneficial effects of isoflavones on human health. *Nutrients* 12 (12), 3853.
- Hayashi, H., Sakai, T., 2012. Biological significance of local TGF- β activation in liver diseases. *Front. Physiol.* 3, 12.
- Hirsch, G.E., Vicieli, P.R.N., de Almeida, A.S., et al., 2017. Natural products with antiplatelet action. *Curr. Pharm. Des.* 23 (8), 1228–1246.
- Hoang, N.T.M., Phuong, T.T., Nguyen, T.T.N., et al., 2016. *In vitro* characterization of derrone as an aurora kinase inhibitor. *Biol. Pharm. Bull.* 39 (6), 935–945.
- Hsiao, Y.-H., Ho, C.-T., Pan, M.-H., 2020. Bioavailability and health benefits of major isoflavone aglycones and their metabolites. *J. Func. Foods* 74, 104164.
- Jiang, B., Han, W.-L., Zhang, Q.-W., et al., 2010. Chemical constituents from the aerial roots of *Ficus microcarpa*. *J. Chin. Med. Mater.* 35 (6), 904–908.
- Jung, Y., Shin, S.Y., Yong, Y., et al., 2015. Plant-derived flavones as inhibitors of aurora B kinase and their quantitative structure-activity relationships. *Chem. Biol. Drug. Des.* 85 (5), 574–585.
- Kang, M.J., Kim, S.Y., Kwon, E.B., et al., 2019. Derrone induces autophagic cell death through induction of ROS and ERK in A549 cells. *PLOS One* 14 (6), e0218659.
- Kelm, J.M., Timmins, N.E., Brown, C.J., et al., 2003. Methods for generation of homogeneous multicellular tumor spheroids applicable to a wide variety of cell types. *Biotechnol. Bioeng.* 83 (2), 173–180.
- Kim, I.-S., 2021. Current perspectives on the beneficial effects of soybean isoflavones and their metabolites for humans. *Antioxidants* 10 (7), 1064.
- Kuang, Y., Lin, Y., Li, K., et al., 2017. Screening of hepatoprotective compounds from licorice against carbon tetrachloride and acetaminophen-induced HepG2 cells injury. *Phytomedicine* 34, 59–66.
- Lareu, R.R., Zeugolis, D.I., Abu-Rub, M., et al., 2010. Essential modification of the sircol collagen assay for the accurate quantification of collagen content in complex protein solutions. *Acta Biomater.* 6 (8), 3146–3151.
- Lee, J., Oh, W.K., Ahn, J.S., et al., 2009a. Prenylisoflavonoids from *Erythrina senegalensis* as novel HIV-1 protease inhibitors. *Planta Med.* 75 (3), 268–270.
- Lee, J.S., Hattori, M., Kim, J., 2008a. Inhibition of HIV-1 protease and RNase H of HIV-1 reverse transcriptase activities by long-chain phenols from the sarcotestas of *Ginkgo biloba*. *Planta Med.* 74, 532–534.
- Lee, J.S., Miyashiro, H., Nakamura, N., Hattori, M., 2008b. Two new triterpenes from the rhizome of *Dryopteris crassirhizoma*, and inhibitory activities of its constituents on human immunodeficiency virus-1 protease. *Chem. Pharm. Bull.* 56 (5), 711–714.
- Lee, S.L., Kim, C.H., Hoang, D.M., et al., 2009b. Genistein-derivatives from *Tetracera scandens* stimulate glucose-uptake in L6 myotubes. *Biol. Pharm. Bull.* 32 (2), 504–508.
- Luan, N.N.T., Okada, T., Yokoyama, T., et al., 2024. Divergent total synthesis of isoflavone natural products and their potential as therapeutic agents for TTR amyloidosis. *J. Nat. Prod.* 87 (11), 2604–2614.
- Máximo, P., Lourenco, A., Feio, S.S., et al., 2002. A new prenylisoflavone from *Ulex jussiaei*. *Z. Naturforsch. C. J. Biosci.* 57 (7–8), 609–613.
- Meringdal, J.W., Menche, D., 2025. Suzuki-Miyaura (hetero-)aryl cross-coupling: recent findings and recommendations. *Chem. Soc. Rev.* 54 (12), 5746–5765.
- Miadokova, E., 2009. Isoflavonoids - an overview of their biological activities and potential health benefits. *Inter. Toxicol.* 2 (4), 211–218.
- Molagoda, I.M.N., Sanjaya, S.S., Lee, K.T., et al., 2023. Derrone targeting the TGF type 1 receptor kinase improves bleomycin-mediated pulmonary fibrosis through inhibition of smad signaling pathway. *Int. J. Mol. Sci.* 24 (8), 7265.
- Mosmann, T., 1983. Rapid colorimetric assay for cellular growth and survival: Application to proliferation and cytotoxicity assays. *J. Immunol. Methods* 65 (1–2), 55–63.
- Mouelle, E.N.M., Nsangou, M.F., Fofack, H.M.T., et al., 2025. *In vitro* and *in silico* studies of the biological activities of some secondary metabolites belonging to *Ficus sur* Forssk (Moraceae): Towards optimization of wightone metabolite. *Chem. Biodivers.* 22 (1), e202401270.
- Muiva-Mutisiya, L., Macharia, B., Heydenreich, M., et al., 2014. 6 α -Hydroxy- α -toxicarol and (+)-tephrodin with antiplasmodial activities from *Tephrosia species*. *Phyto. Lett.* 10, 179–183.
- Nahar, L., Abdelfattah, G.M., Habibi, E., et al., 2026. Isoderrone: A rare bioactive pyranisoflavone with therapeutic potential. *J. Nat. Prod. Disc.* 5 (3), 3745.
- Oh, W.K., Lee, C.H., Seo, J.H., et al., 2009. Diacylglycerol acyltransferase-inhibitory compounds from *Erythrina senegalensis*. *Arch. Pharm. Res.* 32 (1), 43–47.
- Oyama, S.D., de Souza, L.A., Baldoqui, D.C., et al., 2013. Prenylated flavonoids from *Maclura tinctoria* fruits. *Quim. Nova* 36 (6), 800. U115.
- Rahailson, L., Hamburger, M., Hostettmann, K., et al., 1991. Bioautographic agar overlay method for the detection of antifungal compounds from higher plants. *Phytochem. Anal.* 2, 199–203.
- Rao, K.S.R.M., Iyer, C.S.R., Iyer, P.R., 1987. Synthesis of Alpinum isoflavone derrone and related pyranisoflavones. *Tetrahedron* 43 (13), 3015–3019.
- Richter, E.E., Derace, W., Wojtaszewski, J.F.P., 2001. Glucose, exercise and insulin: emerging concepts. *J. Physiol.* 535 (2), 313–322.
- Ro, J.Y., Cho, H.J., 2019. *Cudrania tricuspidata* root extract (CTE) has an anti-platelet effect via cGMP-dependent VASP phosphorylation in human platelets. *J. Kor. Acad. Indust. Coop. Soc.* 20, 298–305.
- Rufer, C.E., Kulling, S.E., 2006. Antioxidant activity of isoflavones and their major metabolites using different *in vitro* assays. *J. Agric. Food Chem.* 54 (8), 2926–2931.
- Sarker, S.D., Nahar, L., 2024. Computational Phytochemistry, 2nd edition. Elsevier, UK.
- Sarker, S.D., Nahar, L., Miron, A., Guo, M., 2020. Medicinal natural products – a disease-focused approach. In: Sarker, S.D., Nahar, L. (Eds.), *Anticancer natural products*, *Ann. Rep. Med. Chem.* 55. Elsevier, UK, pp. 45–75.
- Setchell, K.D.R., Cassidy, A., 1999. Dietary isoflavones: biological effects and relevance to human health. *J. Nutr.* 129 (3), 758S–767S.
- Shin, J.H., Irfan, M., Rhee, M.H., et al., 2021. Derrone inhibits platelet aggregation, granule secretion, thromboxane A₂ generation, and clot retraction: an *in vitro* study. *Evid. Based Complement. Alt. Med.* 2021, 8855980.
- Sknepnek, A., Miletic, D., Stupar, A., et al., 2025. Natural solutions for diabetes: the therapeutic potential of plants and mushrooms. *Front. Nutr.* 12, 1511049.
- Swati, K., Bhatt, P., Singh, S., et al., 2026. Plant-derived natural products as antidiabetic agents. *Stud. Nat. Prod. Chem.* 88, 55–100.
- Trinh, B.T.D., Jager, A.K., Staerk, D., 2017. High-resolution inhibition profiling combined with HPLC-HRMS-SPE NMR for Identification of PTP1B inhibitors from Vietnamese plants. *Molecules* 22 (7), 1228.
- Tsafak, B.T., Ponou, B.K., Teponno, R.B., et al., 2017. Integracide K: a new tetracyclic triterpenoid from *Desmodium uncinatum* (Jacq.) DC. (Fabaceae). *Nat. Prod. Sci.* 23 (2), 113–118.
- Tsukayama, M., Kawamura, Y., Tahara, H., 1992. Synthesis of 4',5'- and 3', 4', 5'-oxygenated pyranisoflavones: Alpinum isoflavone and related compounds, and a revised structure of derrone. *Heterocycles* 34, 505–514.
- Veitch, N.C., 2013. Isoflavonoids of the Leguminosae. *Nat. Prod. Rep.* 30 (7), 988–1027.
- Vong, S.-K., Chen, C.-M., Das, A., et al., 2025. Stimulation of glucose uptake by edible *Pholiota nameko* (T. Ito) S. Ito & S. Imai extract counteracts palmitate-induced insulin resistance in C2C12 myotubes. *Front. Sustain. Food Syst.* 9, 1520875.
- Wang, L., Li, C., Luo, K., 2024. Biosynthesis and metabolic engineering of isoflavonoids in model plants and crops: a review. *Front. Plant. Sci.* 15, 1384091.
- Willems, E., Dedobbeleer, M., Digregorio, M., et al., 2018. The functional diversity of aurora kinases: a comprehensive review. *Cell. Div.* 13, 7.
- Yin, Y.-Z., Wang, R.-S., Chen, R.-D., et al., 2012. Chemical constituents from cell suspension cultures of *Cudrania tricuspidata*. *China J. Chin. Mater. Med.* 37 (24), 3734–3737.