

The Impact of Saponins on Health-Review

Audrey Bouzier¹, Janne Rojas², Sidrine Kerthy Koumba Ibanga^{1,3,*} , Ahmed Lamarti⁴, Patrick Martin^{1,3}, Marielba Morillo⁵

- ¹ University of Artois, University Institutes of Technology of Bethune, F-62408, audreybzr26@gmail.com (A.B.);
² Organic Biomolecular Research Group, Faculty of Pharmacy and Bioanalysis, University of Los Andes, Mérida 5101, Venezuela; janner@ula.ve (J.R.);
³ University of Artois – UniLaSalle, Transformation and Agroressource Unit – URL7519, F-62408 Bethune ; sidrine.koumbaibinga@univ-artois.fr (S.K.K.I.); patrick.martin@univ-artois.fr (P.M.) ;
⁴ Laboratory of Plant Biotechnology, Biology Department, Faculty of Sciences, Abdelmalek Essaadi University, Tetouan, Morocco, lamarti.ahmed58@gmail.com (A.L.);
⁵ Ecology and Nutrition Research Group, Faculty of Pharmacy and Bioanalysis, University of Los Andes, Mérida 5101, Venezuela; marimorillo@gmail.com (M.M.);
* Correspondence: sidrine.koumbaibinga@univ-artois.fr (S.K.K.I.);

Scopus Author ID57222375670

Received: 29.05.2022; Accepted: 21.06.2022; Published: 26.09.2022

Abstract: Saponins have been studied for more than four decades, and their relevance is due to their numerous biological and chemical activities. Indeed, saponins are attracting attention for their industrial exploitation in connection with their pharmacological properties. Saponins also find many applications in the food and cosmetics industries due to their foaming and emulsifying properties. On the other hand, depending on the type of saponin, the species that ingest it, and the context, they are more or less toxic to the body. This article describes a number of investigations work carried out on saponins to determine the impact of saponins on health.

Keywords: phytotherapy; biological and chemical activities; industrial exploitation; pharmaceutical industry; food industry; cosmetics industry; foaming and emulsifying properties; toxicity.

© 2022 by the authors. This article is an open-access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Saponins are a group of secondary metabolites widely distributed in the plant kingdom and some marine species. These are generally found in the roots, leaves, fruits, flowers, and seeds of plants [1, 2].

According to literature, saponin molecules contain a polar glycone structure moiety composed of up to four carbohydrate molecules linked by a glycosidic bond (C-O-sugar bond) at C-3 to the nonpolar aglycone structure moiety, also known as sapogenin [1, 3]. Depending on their aglycone counterparts, saponins might be divided into three main basic structures; steroidal, triterpenoid, and Alkaloid saponins [1, 4].

Saccharide moiety has a variety of hexoses (pyranose ring) or pentoses (furanose ring) sugars, which may be Dextro (D) or Levo (L) isomers of α and β configuration. The most common hexose sugar in saponins is rhamnose, arabinose, xylose, glucose, and ribose. These form mono, di, tri, and tetra-saccharide saponin structures [1, 5–7].

A wide range of investigations on saponins has been conducted for several years. These studies have detailed the surfactant properties of these molecules, which have been attributed to their amphiphilic structure, consisting of a combination of lipophilic nonpolar aglycone and hydrophilic polar glycone moieties [6]. The hydrophilic polar glycone part of saponins, which is soluble in water, consists of sugar chains, and the lipophilic nonpolar aglycone part, which is insoluble in water, is either a steroid or a triterpenoid [8]. In this matter, saponins belong to a class of non-ionic surfactants and hence exhibit surfactant properties such as surface activity, micellization, foaming, detergency, wetting, and emulsification, among others [1, 9].

The most common biological activity attributed to saponins is the ability to lyse erythrocytes [10, 11]. Hemolysis of red blood cells could result from the formation of complexes between saponins and the cell membrane cholesterol leading to pore formation and cell permeabilization and also causing alterations in the negatively charged carbohydrate portions on the cell surface [7, 12]. However, literature also describes that saponins have shown several medicinal properties such as anti-inflammatory, antibacterial, antifungal, antiviral, insecticidal, anticancer, cytotoxic, and molluscicidal action. Moreover, saponins are described to exhibit hypocholesterolemic action in animals and humans [4, 5, 13, 14].

Outstanding the variety of medicinal uses attributed to saponins and in order to understand the relationship between the chemical structure and its medical or pharmaceutical behavior, researchers have increased the attention to the study of these molecules. The present review aims to summarize the most recent investigations regarding saponins, new molecules, and biological and pharmacological activities reported to assess the impact of saponins on health.

2. Saponins, Basic Concepts

2.1. Structure of saponins.

Saponins are generally known as non-volatile, surface-active compounds widely distributed in nature [6]. They are naturally occurring bioorganic amphiphilic glycosides containing nonpolar aglycones and polar glycone structure moieties (sugars) (Figure 1).

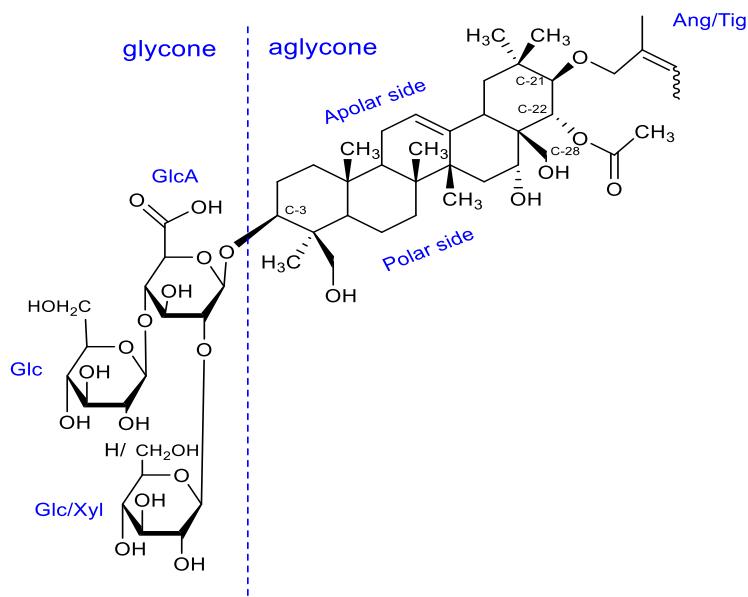


Figure 1. Saponin structure example with the glycon and aglycone part.

Saponins are a group of molecules classified into two main classes, including triterpenoid and steroid saponins. Each class of saponins derives from a precursor molecule containing 30 carbon atoms [15]. The study by Viken et al. reports the classification of saponins based on available structures. Based on carbon skeletons whose formation follows the main pathways for the biosynthesis of aglycones, 11 main classes of saponins have been differentiated: dammaranes, tirucallanes, lupanes, hopanes, oleananes, taraxasteranes, ursanes, cycloartanes, lanostanes, cucurbitanes, and steroids [6]. Some of these main classes (dammaranes, lupanes, hopanes, oleananes, ursanes, and steroids) were further subdivided into 16 subclasses because their carbon skeletons are subjected to minor rearrangement, homologation, cleavage, and degradation reactions [6]. Some other compounds have been considered saponins, such as the glycosidic alkaloids [16].

Triterpenoid glycosides are the most widely distributed in the plant kingdom. These molecules are composed of isoprene units derived from the mevalonate pathway building a pentacyclic compound with 30 carbon atoms (Figure 2-a). The Steroid glycosides are derived triterpenoids with two main ring structures, including the structure of tetracyclic six-membered rings and bicyclic five-membered rings containing 27 carbon atoms. The steroid glycoside core structure consists of two hetero rings, including a furan and a pyran ring (Figure 2-b). Finally, the alkaloid aglycone has a piperidine ring (six-membered ring containing N-atom) instead of a pyranose ring (six-membered ring containing O-atom) in steroid glycosides [1, 5].

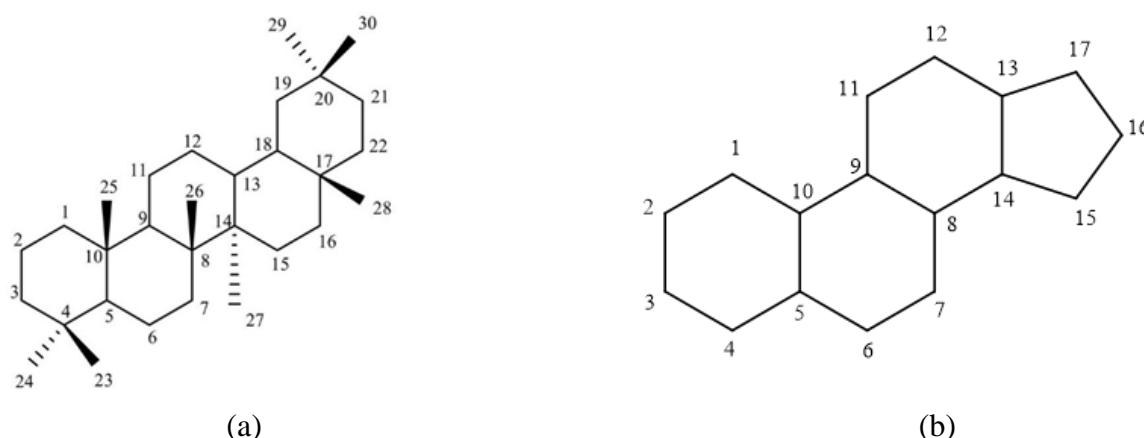


Figure 2. Structures of aglycones: (a) Triterpenoid skeleton [17]; (b) Steroid skeleton.

Sugars constitute the hydrophilic part of saponins. They can consist of one or more osidic chains (branched or linear) with different positions on the aglycone. Based on the number of sugar units, saponins are classified into monodesmosidic, bidesmosidic, or tridesmosidic. Tetradesmosidic saponins have been decrypted but appear rare [18, 19]. Monodesmosidic saponins have a single sugar unit attached to carbon-3. Steroidal and triterpenes saponins are often monodesmosidic saponins. Bidesmosidic saponins have two sugar units attached to C-3 and C-26 or 28. Bidesmosidic saponins are found among the triterpene saponins of the oleanane type with a bond at C-3 and C-28 and for the steroidal saponins of the furostane type with a bond at C-3 and C-26 [20]. Tridesmosidic saponins consist of three sugar units attached. Among the triterpene saponins of the cycloartane type, one can find tridesmosidic structures; the sugar chains are fixed in C-3, C-6, C-24 [21], and, C-3, C-24, and C-25 [22].

The most common sugars are simple dietary sugars such as glucose, galactose, rhamnose, arabinose, xylose, and ribose, although a wide variety of sugars occur naturally [1, 5–7].

Other functional groups such as hydroxyl ($-\text{OH}$), carboxylic acid ($-\text{COOH}$), ester ($-\text{COOR}$), and methyl ($-\text{CH}_3$) can be found in steroidal and triterpene saponins, making a variety of molecules such as organic acids and esters that may also be attached to the aglycone through carboxylic groups (COOH). These are particularly sugar acids, such as glucuronic acid and galacturonic acid, which are oxidized forms of sugar.

2.2. Sources of saponins.

Saponins-producing plants are found in various geographical regions and climatic zones around the world. They are widely distributed in the plant kingdom and in a few marine sources. The saponin distribution among the organs of a plant varies considerably. They are found in both aerial and underground parts such as stems, roots, rhizomes, pericarp, leaves, fruits, flowers, bulbs, and seeds [3, 23, 24].

Triterpenoid saponins are mainly present in dicotyledonous (families such as Caryophyllaceae, Caprifoliaceae, Araliaceae) plants, while steroid saponins are mainly present in monocotyledonous plants (families such as Asparagaceae, Agavaceae, Liliaceae, and Zygophyllaceae) [3, 24, 25].

The plants richest in saponins belong to the family Solanaceae: tomato (*Solanum lycopersicum*), eggplant (*Solanum melongena*), and potato (*Solanum tuberosum*). They are also found in legumes (peas, soybeans, etc.) and in plants such as spinach (*Spinacia oleracea*), asparagus (*Asparagus officinalis*), chestnuts (*Castanea* spp), and quinoa (*Chenopodium quinoa*).

3. New molecules of saponins isolated from different plant species in the last 10 years (2012–2022)

3.1. Newly isolated saponins.

Plants have always been used as traditional foods and medicines. Natural preparations obtained from plants have played a remarkable role in drug discovery. With the rapid development of separation and analytical methods, more and more new biologically active components, such as saponins, have been isolated. Saponins have been the subject of great attention by all chemists in recent years. New molecules and numerous derivatives with diverse activities have been reported.

This section provides a non-exhaustive list (Table 1) of new saponins molecules isolated from different plant species in the last 10 years (2012–2022). These new saponins represent a significant advance in science and research. Their structures were elucidated by combined spectroscopic and spectrometric techniques (^1H NMR, ^{13}C NMR, HSQC, ^1H - ^1H COSY, HMBC, TOCSY, NOESY, HRESIMS, GC–MS) and chemical methods by comparing published data. The properties of some of these molecules have been evaluated and have shown pharmacological activities, immunomodulatory effects, and hemolytic toxicity. Other properties have also been found.

As reported in previous works, saponins are distributed between monocotyledonous and dicotyledonous angiosperms. Thus, steroid saponins are predominantly present in

monocotyledonous angiosperms such as Agavaceae, Asparagaceae, Dioscoreaceae, Dracaenaceae, and Liliaceae. Steroidal saponins are exceptionally found in the following dicotyledons: Solanaceae, Zygophyllaceae, Asteraceae.

The triterpene saponins predominantly present in dicotyledons have been isolated from the following families: Aquifoliaceae, Asteraceae, Caryophyllaceae, Caprifoliaceae, etc.

In the Araliaceae family, oleanane type triterpenoid saponins were isolated. Oleane was also isolated from *Bellis sylvestris* (Asteraceae), *Ardisia crispa* (Myrsinaceae), and *Corrigiola litoralis* (Caryophyllaceae) [26–28]. All compounds isolated from *Bellis sylvestris* were monodesmoside with bayogenin as the aglycone and an oligosaccharide (two to four sugar unities) moiety esterified at C-28 carbon. One compound was a bisdesmoside esterified at C-3 carbon. New oleane triterpenoid saponins isolated from the roots of *Ardisia crispa* (Myrsinaceae) named Ardisiacrispin D–F were the initial proof that the monosaccharide was a non-arabinopyranose component and directly associated with aglycone C-3 of triterpenoid saponins in the *Ardisia* genus. Triterpenoids have been isolated from *Ilex* species of the Aquifoliaceae family. Six new triterpenes saponins, asprellanosides A–F, were isolated from the roots of *Ilex asprella* species. Two of these compounds (19α -hydroxyursolic acid 3-*O*- β -D-(2'-*O*-acetylxylopyranoside) and $3\beta,19\alpha$ -dihydroxyolean-12-en-23,28-dioic acid 28-*O*- β -D-glucopyranoside), as well as three other known molecules, have shown significant cytotoxic activities against human tumor cell line A549 [29]. From *Ilex cornuta*, five new triterpenoid saponins were isolated from the aerial parts. Two new compounds exhibited significant cell-protective effects against H₂O₂ – induced H9C2 cardiomyocyte injury.

Much attention has been paid to studies of the biological activities of *Tupistra chinensis* species. Indeed, it has been shown that saponins, especially spirostanol saponins, play an essential role in the chemical composition of *T. chinensis*. This is because studies have reported total saponins of *T. chinensis* since these molecules have shown the ability to inhibit tumor cell proliferation *in vivo* and *in vitro* [30–34].

Table 1. New saponins molecules isolated from different plant species in the last ten years (2012–2022).

Family	Species	Plant part	Saponin type	References
Acanthaceae	<i>Pseuderanthemum carruthersii</i> (SEEM.) GUILL. var. <i>atropurpureum</i> (BULL.) FOSB.	Roots	Triterpenoid	[35]
Agavaceae	<i>Agave offoyana</i>	Flowers	Steroidal	[36]
	<i>Dracaena thaliooides</i>	Leaves	Steroidal	[37]
	<i>Dracaena cambodiana</i>	Dragon's blood	Steroidal	[38]
	<i>Yucca desmettiana</i>	Leaves	Steroidal	[39]
	<i>Yucca elephantipes</i>	Leaves	Steroidal	[40]
	<i>Yucca glauca</i>	Underground parts	Steroidal	[41]
	<i>Yucca schidigera</i>	Stems	Steroidal	[42]
Aquifoliaceae	<i>Ilex asprella</i>	Roots	Triterpenoid	[29]
	<i>Ilex cornuta</i>	Aerial parts	Triterpenoid	[43]
	<i>Ilex kudingcha</i> C. J. Tseng.	Leaves	Triterpenoid	[44]
Araliaceae	<i>Aralia taibaiensis</i>	Root bark	Triterpenoid	[45]
	<i>Dizygotheca elegantissima</i> R.	Aerial parts	Triterpenoid	[46]
	<i>Hydrocotyle bonariensis</i>	Underground parts	Triterpenoid	[47]
	<i>Panax japonicus</i>	Roots	Triterpenoid	[48]
	<i>Panax notoginseng</i>	Fruits, roots, leaves	Triterpenoid	[49]
	<i>Tetrapanax papyriferus</i>	Pith	Steroidal	[50]
Asparagaceae	<i>Anemarrhena asphodeloides</i> Bge.	Dragon's blood	Steroidal	[51]
	<i>Dracaena cambodiana</i>	Bark, roots, leaves	Steroidal	[52]
	<i>Dracaena fragrans</i> (L.)	Bark	Steroidal	[53]
	<i>Dracaena viridiflora</i>	Roots	Steroidal	[54]
	<i>Dracaena marginata</i>	Aerial parts	Steroidal	[55]
	<i>Sansevieria cylindrica</i>	Aerial parts	Steroidal	[56]

Family	Species	Plant part	Saponin type	References
	<i>Sansevieria trifasciata</i>	Roots	Steroidal	[57]
	<i>Tupistra chinensis</i>	Roots, rhizomes	Steroidal	[58]
Asteraceae	<i>Atractylis flava</i>	Whole plant	Triterpenoid	[59]
	<i>Bellis sylvestris</i> Cyr.	Leaves	Triterpenoid	[26]
Amaranthaceae	<i>Salicornia herbacea</i>		Triterpenoid	[60]
Caryophyllaceae	<i>Corrigiola litoralis</i>	Roots	Triterpenoid	[28]
	<i>Gypsophila pilulifera</i> Boiss. & Heldr.	Roots	Triterpenoid	[61]
	<i>Polycarpea corymbosa</i> Lamk	Roots, leaves	Triterpenoid	[62]
	<i>Silene viscidula</i>	Roots	Triterpenoid	[63]
Caprifoliaceae	<i>Cephalaria sumbuliana</i> Gokturk	Aerial parts	Triterpenoid	[64]
	<i>Lonicera macranthoides</i>	Flower	Triterpenoid	[65, 66]
	<i>Patrinia scabiosifolia</i>	Whole plant	Triterpenoid	[67]
	<i>Lonicera similis</i> Hemsl.	Buds	Triterpenoid	[68]
Cucurbitaceae	<i>Gynostemma pentaphyllum</i>	Aerial parts	Triterpenoid	[69, 70]
Dioscoreaceae	<i>Dioscorea bulbifera</i> var. <i>sativa</i> .	Flowers	Steroidal	[71]
	<i>Dioscorea nipponica</i>	Rhizomes	Steroidal	[72]
	<i>Dioscorea zingiberensis</i>	Rhizomes	Steroidal	[73]
	<i>Dioscorea preussii</i>	Rhizomes	Steroidal	[74]
Dracaenaceae	<i>Sansevieria trifasciata</i>	Aerial part	Steroidal	[57]
	<i>Sansevieria cylindrica</i>	Aerial part	Steroidal	[56]
Fabaceae	<i>Abrus precatorius</i>	Leaves, stems	Triterpenoid	[75]
Iridaceae	<i>Iris florentina</i>	Underground parts	Steroidal	[76]
Liliaceae	<i>Allium cepa</i> L.	Bulbs	Steroidal	[77]
	<i>Allium tuberosum</i>	Roots	Steroidal	[78]
	<i>Bessera elegans</i>	Bulbs	Steroidal	[79]
	<i>Chamaelirium luteum</i>	Underground parts	Steroidal	[80]
	<i>Anemarrhena asphodeloides</i>	Rhizomes	Steroidal	[81]
	<i>Tupistra chinensis</i>	Roots, rhizomes	Steroidal	[82]
	<i>Tupistra chinensis</i>	Rhizomes	Steroidal	[83]
	<i>Tupistra chinensis</i>	Rhizomes	Steroidal	[33]
	<i>Tupistra chinensis</i>	Rhizomes	Steroidal	[84]
	<i>Tupistra chinensis</i>	Rhizomes	Steroidal	[34]
	<i>Tupistra chinensis</i>	Roots	Steroidal	[85]
	<i>Tupistra chinensis</i>	Roots	Steroidal	[86]
	<i>Tupistra chinensis</i>	Roots, rhizomes	Steroidal	[87]
	<i>Smilacina japonica</i>	Roots, rhizomes	Steroidal	[88]
	<i>Ypsilandra thibetica</i>	Whole plants	Steroidal	[89]
Melanthiaceae	<i>Paris delavayi</i>	Rhizomes	Steroidal	[90]
	<i>Paris vaniotii</i>	Rhizomes	Steroidal	[91]
Mimosaceae	<i>Albizia adianthifolia</i>	Stem	Triterpenoid	[92]
Myrsinaceae	<i>Ardisia kivuensis</i>	Stems	Triterpenoid	[93]
	<i>Ardisia crispa</i>	Roots	Triterpenoid	[27]
Nartheciaceae	<i>Narthecium ossifragum</i>	Flowers	Steroidal	[94]
Pittosporaceae	<i>Pittosporum senacia</i> Putterlick	Branches	Triterpenoid	[95]
Primulaceae	<i>Cyclamen africanum</i>	Roots	Triterpenoid	[96]
Ranunculaceae	<i>Clematis heracleifolia</i>	Whole plant	Triterpenoid	[97]
	<i>Helleborus thibetanus</i>	Roots and rhizomes	Steroidal	[98]
	<i>Eranthis cilicica</i>	Tubers	Steroidal	[99]
	<i>Eranthis section Shibateranthis</i>	Tubers	Steroidal	[100]
Rosaceae	<i>Sanguisorba officinalis</i>	Roots	Triterpenoid	[101]
Rubiaceae	<i>Gardenia jasminoides</i> Ellis	Root	Triterpenoid	[102]
Sapindaceae	<i>Xanthoceras Sorbifolia</i> Bunge	Husks	Triterpenoid	[103]
Solanaceae	<i>Solanum Incanum</i>	Roots	Steroidal	[104]
	<i>Solanum melongena</i> L	Seeds	Steroidal	[105]
	<i>Solanum xanthocarpum</i>	Fruits	Steroidal	[106, 107]
Theaceae	<i>Camellia oleifera</i>	Defatted seeds	Triterpenoid	[108]
Valerianaceae	<i>Patrinia scabiosifolia</i> Fisch.	Whole plants	Triterpenoid	[67]
Zygophyllaceae	<i>Fagonia indica</i>	Aerial parts	Steroidal	[109]
	<i>Tribulus terrestris</i> L	Whole plant	Steroidal	[110]
	<i>Tribulus terrestris</i>	Aerial parts	Steroidal	[111]
	<i>Zygophyllum cornutum</i> Coss	Aerial parts	Triterpenoid	[96]

4. Studies on the Biological and Pharmacological Properties of Saponins in the Last 10 Years

Numerous studies have led to the discovery of many biological and pharmacological roles of saponins. More than forty saponins-related biological activities have been listed [25]. Juang and Liang published a review dealing with the biological and pharmacological activities of steroid and terpenoid synthetic saponins [112]. These studies represent a real breakthrough for industry and medicine. This section will describe the most recent research and results concerning these kinds of molecules' biological and pharmacological activities. It is important to note that several families of plants will have various biological and pharmaceutical activities [11, 113–117].

4.1. Antimicrobial activity.

Classified as belonging to the Caprifoliaceae family, the *Cephalaria* genus is a rich source of attractive secondary metabolites, which include saponins that have several important biological activities, such as antimicrobial activities [118]. Phytochemical screening of fruit, leaf, and stem extracts of *S. incanum* has shown antimicrobial efficacy against *Escherichia coli*, *Salmonella typhi*, *Bacillus subtilis*, and *Staphylococcus aureus* [119]. *Dracaena* and *Sansevieria* have antimicrobial activity [120]. One spirostanol isolated from the dragon's blood of *Dracaena cambodiana* possessed an inhibitory effect on *S. aureus* [52].

The genus *Yucca* also has antimicrobial activity [121, 122]. *Pittosporum* plants are known for their antibacterial and antifungal properties. The ethyl acetate fractions of the leaves of *P. tobira* showed antibacterial activity with bacteria responsible for dental caries (*Porphyromona gingivalis*, *Prevotella intermedia*, and *Fusobacterium nucleatum*) [123].

The study by Fang *et al.* on the roots of *Allium tuberosum* showed the role of the polar moiety in the inhibition of bacterial growth. Indeed, they reported that saponins with a C-3 saccharide moiety without any C-2 oxygen functionality exhibited potent antibacterial activities against *B. subtilis* (32 µg/mL) and *E. coli* (16 µg/mL) (positive control, kanamycin: 2 lg/mL), indicating that 2-OH was negative for antibacterial activities [78].

4.2. Cytotoxic and antitumor activity.

Based on *in vitro* bioassays, saponins have been reported to possess cytotoxic and antitumor activity [124]. Many studies demonstrate the inhibitory effect of total saponins on cell proliferation and apoptosis in A549 cells [31]. Saponins extracted from *Cirsium japonicum* DC exhibited a good antiproliferative effect against cancer cells, especially A549 cells, which might result from the promotion of Reactive Oxygen Species (ROS) generation in cancer cells [125].

The genus *Tupistra* (Liliaceae) has been well studied for the last ten years. *Tupistra chinensis* have revealed that compounds such as steroidal saponins consisting of spirostanol saponins and furostanol saponins are the most abundant in this species. *T. chinensis* Baker, described as an antitumor folk herb, has been studied to understand the antitumor mechanism of the total steroidal saponins of this plant. The result showed that *Tupistra chinensis* exhibited significant anti-gastric cancer effects *in vitro* and *in vivo* [126]. T-17, a bioactive spirostanol saponin extracted from *T. chinensis* Baker, is simultaneously involved in apoptosis and induced autophagy [32]. New spirostanol saponins isolated from *Tupistra chinensis* bark showed

cytotoxicity against A549 cells (IC_{50} $52.66 \pm 3.12 \mu\text{mol L}^{-1}$) and H1299 cells (IC_{50} $57.29 \pm 2.51 \mu\text{mol L}^{-1}$) [58]. Spirostanol and furostanol saponins isolated from the rhizome of *T. chinensis* showed cytotoxic activity against A549, HepG 2, and Caski cancer cell lines, K562 cells, and significant inhibition of nitric oxide production [34,87]. Tupisteroide C isolated from de roots of *T. chinensis* exhibited cytotoxicity against A549 cancer cell lines with IC_{50} values of $25.0 \mu\text{M}$ [86]. New polyhydroxylated furostanol showed cytotoxicity against human cancer cell lines SW620 and HepG2 [33]. Another study revealed the antineoplastic constituents of *T. chinensis*. Indeed, two steroid saponins showed moderate cytotoxic activity against most of five cultured human tumor cell lines (HL-60, SMMC-7721, A-549, MCF-7, and SW480). This study has suggested that the sugar moiety plays a key role in biological activity and that steroid saponins possess more cytotoxic activity than their sapogenins [82].

The phytochemical study of the underground parts of *Hydrocotyle bonariensis*, revealed weak cytotoxicity of two triterpenoid saponins against two human colon cancer cell lines (HT-29 and HCT 116) [47].

Four new oleanane saponins and three known saponins were isolated from the aerial parts of *Dizygotheca elegantissima* R. Vig. & Guillaumin. The antiproliferative activity of all isolated compounds was assessed [46]. A review related to *Dracaena* and *Sansevieria* species underlined their remarkable antiproliferative actions [120].

Gynostemma pentaphyllum (Thunb.) Makino (GpM) (Jiaogulan) has anticancer activities, including stopping the cell cycle, apoptosis, and inhibition of invasion and metastases [127]. *Ypsilandra thibetica* belongs to the family Liliaceae have shown antitumor activity [113]. Several new saponins isolated from *Camellia oleifera* Abel (TSSC) have antiproliferative activity against human tumor cells *in vitro*. TSSC induced cancer cell apoptosis in mice with solid liver tumors [128].

4.3. Antioxidant properties.

Oxidative stress is the result of a disparity in the balance between oxidizing (reactive oxygen species) and defense systems (antioxidants), resulting in irreversible damage to the cell. Following a renewed interest in discovering medicines from plant sources, the *Yucca* genus has been studied, and amazing therapeutic capabilities have emerged, including antioxidant properties [121]. *Panax notoginseng* (Burk) F. H. Chen has antioxidant shares [129]. *Salicornia herbacea* L., which grows in salt marshes and muddy shores along the west coast of Korea, has been used as a vegetable seasoning and popular medicine. Still, it also has antioxidant action [130]. Ardisinol III, a new alketylresorcinol isolated from MeOH extract of *Ardisia kivuensis* fruit, exhibits a weak antioxidant activity (IC_{50} $109.8 \mu\text{g/mL}$) compared to the reference L-ascorbic acid (IC_{50} $3.9 \mu\text{g/mL}$) [131]. *F. indica* is a very important medicinal plant due to its various of therapeutic uses, such as antioxidants [115]. Pharmacological studies have shown that the observed *Ficus* species have a wide range of biological properties, including antioxidant effects [132].

The triterpenoid 30-norhederagenin 3-O- β -d-glucuronopyranosyl-28-O- β -d-glucopyranoside isolated from the n-BuOH fraction of *S. herbacea* has potential as a natural antioxidant since it showed a significant scavenging effect on peroxynitrite [60].

Oleanane-type triterpenoid saponins isolated from *Aralia taibaiensis* exhibited antioxidant and antiglycation activities. Structure-activity relationship study reveals that

oligosaccharide moiety at C-3 is responsible for the remarkable properties. They also indicated that the double bond in the aglycon is less important for antidiabetic activity [45].

Spirostanol saponin derivatives isolated from *Ruscus hyrcanus* showed 6–85% DPPH radical scavenging activity at 7.8–500 µg/mL concentrations. This study used quercetin as positive control showed 96% inhibition at 200 µg/mL [133].

4.4. Anti-inflammatory properties.

Panax notoginseng (Burk) F. H. Chen, as traditional Chinese medicine, has a long history of great clinical value, such as anti-inflammatory actions [129]. Various saponins from the *Panax* genus (*P. ginseng*, *P. japonicas*, and *P. quinquefolius*) have shown anti-inflammatory effects by inhibiting inflammasome activation such as NLRP1, NLRP3, and AIM2 [134]. Triterpenoid saponins from *Panax stipuleanatus* may act as a suppressing inflammatory mediator [135]. The genus *Yucca* has anti-inflammatory actions [121]. So far, a wide variety of phytochemical components have been isolated from around seventeen species of *Dracaena* and *Sansevieria*. They exhibit various structural patterns and a wide range of biological activities, including remarkable anti-inflammatory effects [120]. T-17, a bioactive spirostanole saponin extracted from *Tupistra chinensis* Baker, has already been reported with anti-inflammatory activities [32, 136]. *Patrinia scabiosifolia* Link (PS), a member of the genus *Patrinia* (family Caprifoliaceae), is traditionally used in popular medicines to treat various inflammatory diseases such as acute appendicitis, ulcerative colitis, and pelvic inflammation [137]. *Dioscorea nipponica* Makino, a perennial medicinal plant of the family Dioscoreaceae, has also revealed anti-inflammatory activity [138]. Butanoic extract enriched with saponin from *Agave brittoniana* showed anti-inflammatory activity by reducing the dry weight of the granuloma and increasing the inhibition percentage [139]. Based on the use of *T. govanianum* rhizomes to treat inflammation, a preliminary study suggests that due to steroid saponins, *T. govanianum* would have the excellent anti-inflammatory potential [140].

4.5. Properties on the cardiovascular, nervous, lymphatic, and pulmonary systems.

Cardiovascular disease (CVD) is the leading cause of death globally. Shi *et al.* reviewed the pharmacologic properties of ginseng saponins, such as their functions in cardiovascular systems, where they can act by controlling reactive oxygen species and nitric oxide production and activate various receptors in endothelial cells [141]. *Gardenia jasminoides* Ellis is a popular shrub of the Rubiaceae family. The dried ripe fruits of this plant are well known and frequently used not only as an excellent natural dye but also as an important traditional medicine for the treatment of various diseases, such as stasis, to activate blood circulation [142]. *Ypsilandra thibetica*, aids gynecological hemorrhagic diseases [113]. *Panax notoginseng* (Burk) F. H. Chen allows inhibition of platelet aggregation [129]. The *Cephalaria* genus belongs to the Caprifoliaceae family and is a rich source of secondary metabolites, mainly including saponins that have several biological properties, such as hemolytic effects. [118]. *Ficus* species have anticoagulant properties [132]. Topical Astragaloside IV eye drops reduced TGFβ2-induced ocular hypertension in mice [143].

Tribulus terrestris L. is a widely distributed perennial plant worldwide, especially in subtropical regions. Its dried fruit has been used in traditional Chinese medicine (TCM) to treat edema, abdominal distension, emission, morbid leucorrhoea, and vitiligo. In addition, *T.*

terrestris can act as an aphrodisiac tonic but is also used to treat cardiovascular diseases. Previous phytochemical studies have reported several saponins and alkaloids in this plant, and several studies have shown that saponins are responsible for the biological activities of *T. terrestris* [144].

Accumulated data indicate that saponins have important neuroprotective effects on mitigating central nervous system disorders, such as stroke, Alzheimer's, Parkinson's, and Huntington's [145]. *Panax notoginseng* (Burk) F. H. Chen can improve mental function, have anti-insomnia and antidepressant effects, relieve anxiety, and decrease neural network excitation [129]. The literature has revealed that *A. adianthifolia* is used as a neurodegenerative disorder [146]. *Salicornia herbacea* L. (glassware, tungtungmadi in Korean) suggests an important role in protecting against glutamate-induced neural damage [130]. Andrographolide (AG) is a natural diterpene lactone with considerable therapeutic potential for treating many diseases, including neurological disorders [147].

Oleiferasaponine A2 has anti-hyperlipidemic activity on cell lines. A more in-depth study of the hypolipidemic mechanism showed that oleiferazine A2 inhibited the synthesis of fatty acids by significantly decreasing the expression of SREBP-1c, FAS, and FAS proteins, while significantly promoting β -oxidation of fatty acids by ascending regulation of expression of ACOX-1, CPT-1 and ACOX-1. The results show that oleiferazine A2 has a potential medicinal value for treating hyperlipidemia [108].

4.6. Antidiabetic properties.

Entada phaseoloides (TSEP) exert an important hypolipidemic effect and improvement of tissue steatosis [148]. *Atractylis flava* Desf (BEAF) contains triterpenes, steroids, saponins, and flavonoids. Melakhessou *et al.* showed the antidiabetic effects *in vitro* and *in vivo* of n-butanol extract from the whole plant of BEAF by reducing blood glucose alloxan-induced diabetic rats, stimulating and inhibiting α -Glucosidase and α -Amylase enzymes. They conclude that plant extract might be a therapeutic resource in treating diabetes and hyperlipidemia [149]. A number of investigations have revealed that *A. adianthifolia* is used as a purgative and herbal therapy for diabetes [146]. *Panax notoginseng* (Burk) F. H. Chen regulates blood glucose [129]. In addition, *Entada phaseoloides* (TSEP) significantly reduce fasting blood sugar [148]. In a recent review, the authors listed the antidiabetic properties of the species *Ficus benghalensis*, *Ficus religiosa*, *Glycyrrhiza glabra* [116, 132].

4.7. Other properties.

Salicornia herbacea (SH) is a halophyte growing in salt marshes along the coast of South Korea. It is mainly known to exhibit a whitening activity on the skin [150]. The literature search revealed that *A. adianthifolia* is used for skin diseases [146]. *Lonicera Linn* is an important genus of the Caprifoliaceae family, which includes about 200 species. Some of these species have been commonly used in traditional Chinese medicine for thousands of years. Besides, some species may also be used in diverse applications, including in functional foods and cosmetics. Saponins are one of the most important bioactive components of *Lonicera Linn* [151]. The roots extracted with *Sanguisorba officinalis* L. water could be a candidate to improve physical performance by inhibiting LDHA and glycolysis [152].

5. Traditional Uses, Risks, and Benefits

Saponins have many benefits, including anticancer, hypolipemic, antioxidant, anti-inflammatory, antidiabetic, antimicrobial, cardiovascular, skin, nervous, musculoskeletal, skeletal, cardiovascular, pulmonary, and lymphatic systems. For example, *Panax notoginseng* (Burk) F. H. Chen, as traditional Chinese medicine, has a long history of great clinical value: inhibition of neuronal apoptosis and neuronal protection. *Gynostemma pentaphyllum* (Thunb.) Makino (GpM) (Jiaogulan) is widely used in Chinese medicine for the treatment of diabetes [127] and cardiovascular disease [127].

Saponins also act on eye problems, gastrointestinal disorders, hemorrhoids, and respiratory difficulties and regulate menstruation.

The genus *Cephalaria*, belonging to the Caprifoliaceae family, is used in traditional medicine to cure heart and lung diseases [118]. *Xanthoceras sorbifolia* Bunge wrappings are mainly used in northern China as traditional medicine. They would have a potential protective effect on cognitive impairment. However, the mechanism remains unclear.

The genus *Cephalaria*, belonging to the Caprifoliaceae family, is used in traditional medicine for rheumatism [118]. The genus *Yucca* has an antiarthritic action [121]. Traditionally, the rhizome of *Dioscorea nipponica* Makino, which is a perennial medicinal plant of the Dioscoreaceae family, has been used in China to treat joint pains, rheumatoid arthritis, pain in the legs and lumbar area, Kashin Beck's disease, bruises, sprains, chronic bronchitis, cough and asthma [138].

However, it is important to be aware since studies have proved that using saponins can represent a health risk. For most saponins, there is a correlation between high hemolytic activity, high toxicity, and high surface activity. They may cause nausea, which seems to be due to interactions between saponins and mucous membranes associated with loss of appetite or vomiting [153]. In addition, dietary saponins have been approved as potent pancreatic lipase inhibitors. They would cause a decrease in lipid synthesis, suppression of adipogenesis, inhibition of intestinal lipid absorption, and promotion of fecal excretion of bile acids and triglycerides [154]. Juszczak *et al.* explained that depending on their concentration, saponin fraction can decrease and increase the level of free radicals generated by H₂O₂ [155]. But also, FAO conducted a study where it was found that saponins have negative effects on humans and large animals [156].

The *Dracaena* and *Sansevieria* species, used in traditional medicines and as indoor ornamental plants for their air purifying properties, are rich sources of bioactive secondary metabolites.

6. Conclusions

Saponins are composed of two main parts: the aglycone and a sugar fraction. They are classified into triterpenoid and steroid compounds. In the last decade, many new saponins extracted from plants have been isolated and characterized in addition to others already known. Some have revealed good biological and pharmacological properties, such as antimicrobial, antidiabetic, and anticancer. Given the previously reported results, we can conclude that saponins are a real opportunity for the pharmaceutical, industrial and extra-pharmaceutical fields. On the other hand, research has cleared that direct injection of saponins into the blood

system may harm the body. However, their dangerousness is controversially discussed due to growing evidence of their beneficial health effects.

Funding

This research received no external funding

Conflicts of Interest

The authors declare no conflict of interest.

Acknowledgments

We would like to apologize in advance to colleagues whose work was overlooked by length limitations or by our ignorance.

References

1. Rai, S.; Acharya-Siwakoti, E.; Kafle, A.; Devkota, H.P.; Bhattacharai, A. Plant-Derived Saponins: A Review of Their Surfactant Properties and Applications. *Sci* **2021**, *3*, 44, <https://doi.org/10.3390/sci3040044>.
2. Oleszek, W.; Hamed, A. Saponin-Based Surfactants. In: *Kjellin, M.; Johansson, I. (Eds.) Surfactants from Renewable Resources 2010*, John Wiley & Sons Ltd, <http://dx.doi.org/10.1002/9780470686607>.
3. Sparg, S.G.; Light, M.E.; van Staden, J. Biological Activities and Distribution of Plant Saponins. *J Ethnopharmacol* **2004**, *94*, 219–243, <https://doi.org/10.1016/j.jep.2004.05.016>.
4. Moghimipour, E.; Handali, S. Saponin: Properties, Methods of Evaluation and Applications. *Annual Research & Review in Biology* **2015**, *5*, 207–220, <http://dx.doi.org/10.9734/ARRB/2015/11674>.
5. Ashour, A.; El Aziz, M.M.A.; Melad, A.S.G. A Review on Saponins from Medicinal Plants: Chemistry, Isolation, and Determination. *Journal of Nanomedicine Research* **2019**, *8*, 282–288, <https://doi.org/10.15406/jnmr.2019.07.00199>.
6. Vincken, J.-P.; Heng, L.; de Groot, A.; Gruppen, H. Saponins, Classification and Occurrence in the Plant Kingdom. *Phytochemistry* **2007**, *68*, 275–297, <https://doi.org/10.1016/j.phytochem.2006.10.008>.
7. Podolak, I.; Galanty, A.; Sobolewska, D. Saponins as Cytotoxic Agents: A Review. *Phytochem Rev* **2010**, *9*, 425–474, <https://doi.org/10.1007/s11101-010-9183-z>.
8. Böttger, S.; Hofmann, K.; Melzig, M.F. Saponins Can Perturb Biologic Membranes and Reduce the Surface Tension of Aqueous Solutions: A Correlation? *Bioorg Med Chem* **2012**, *20*, 2822–2828, <https://doi.org/10.1016/j.bmc.2012.03.032>.
9. Tmáková, L.; Sekretár, S.; Schmidt, Š. Plant-Derived Surfactants as an Alternative to Synthetic Surfactants: Surface and Antioxidant Activities. *Chemical Papers* **2016**, *70*, 188–196, <https://doi.org/10.1515/chempap-2015-0200>.
10. Rao, A.V.; Gurinkel, D.M. The Bioactivity of Saponins: Triterpenoid and Steroidal Glycosides. *Drug Metabol Drug Interact* **2000**, *17*, 211–235, <https://doi.org/10.1515/dmdi.2000.17.1-4.211>.
11. Francis, G.; Kerem, Z.; Makkar, H.P.S.; Becker, K. The Biological Action of Saponins in Animal Systems: A Review. *Br J Nutr* **2002**, *88*, 587–605, <https://doi.org/10.1079/bjn2002725>.
12. Gauthier, C.; Legault, J.; Girard-Lalancette, K.; Mshvildadze, V.; Pichette, A. Haemolytic Activity, Cytotoxicity and Membrane Cell Permeabilization of Semi-Synthetic and Natural Lupane- and Oleanane-Type Saponins. *Bioorg Med Chem* **2009**, *17*, 2002–2008, <https://doi.org/10.1016/j.bmc.2009.01.022>.
13. Cheng, T.-C.; Lu, J.-F.; Wang, J.-S.; Lin, L.-J.; Kuo, H.-I.; Chen, B.-H. Antiproliferation Effect and Apoptosis Mechanism of Prostate Cancer Cell PC-3 by Flavonoids and Saponins Prepared from *Gynostemma Pentaphyllum*. *J Agric Food Chem* **2011**, *59*, 11319–11329, <https://doi.org/10.1021/jf2018758>.
14. Carrillo, M.R.; Mitaine-Offer, A.-C.; Paululat, T.; Pouységu, L.; Quideau, S.; Rojas, L.; Porcar, C.R.; Lacaille-Dubois, M.-A. Two New Oleanane-Type Saponins from *Hydrocotyle Multifida*. *Natural Product Communications* **2018**, *13*, 1453–1456, <https://doi.org/10.1177/1934578X1801301110>.

15. Abe, I.; Rohmer, M.; Prestwich, G.D. Enzymatic Cyclization of Squalene and Oxidosqualene to Sterols and Triterpenes. *Chem. Rev.* **1993**, *93*, 2189–2206, <https://doi.org/10.1021/cr00022a009>.
16. Haralampidis, K.; Trojanowska, M.; Osbourn, A.E. Biosynthesis of Triterpenoid Saponins in Plants. *Adv Biochem Eng Biotechnol* **2002**, *75*, 31–49, https://doi.org/10.1007/3-540-44604-4_2.
17. Khwaza, V.; Mlala, S.; Oyedele, O.O.; Aderibigbe, B.A. Pentacyclic Triterpenoids with Nitrogen-Containing Heterocyclic Moiety, Privileged Hybrids in Anticancer Drug Discovery. *Molecules* **2021**, *26*, 2401, <https://doi.org/10.3390/molecules26092401>.
18. Linnek, J.; Mitaine-Offer, A.; Miyamoto, T.; Tanaka, C.; Paululat, T.; Avunduk, S.; Alankuş-Çalışkan, Ö.; Lacaille-Dubois, M. Cycloartane Glycosides from Three Species of *Astragalus* (Fabaceae). *Helvetica Chimica Acta* **2011**, *94*, 230–237, <https://doi.org/10.1002/hlca.201000157>.
19. Perrone, A.; Masullo, M.; Bassarello, C.; Bloise, E.; Hamed, A.; Nigro, P.; Pizza, C.; Piacente, S. Unusual Cycloartane Glycosides from *Astragalus Eremophilus*. *Tetrahedron* **2008**, *64*, 5061–5071, <https://doi.org/10.1016/j.tet.2008.03.069>.
20. Bruneton, J. *Pharmacognosie-Phytochimie, Plantes Médicinales* **2009**. Lavoisier 4e éd, revue et augmentée, Tec & Dac-Editions médicinales internationales, Paris.
21. Bedir, E.; Calis, I.; Aquino, R.; Piacente, S.; Pizza, C. Secondary Metabolites from the Roots of *Astragalus Trojanus*. *J Nat Prod* **1999**, *62*, 563–568, <https://doi.org/10.1021/np980399t>.
22. Polat, E.; Caliskan-Alankus, O.; Perrone, A.; Piacente, S.; Bedir, E. Cycloartane-Type Glycosides from *Astragalus Amblolepis*. *Phytochemistry* **2009**, *70*, 628–634, <https://doi.org/10.1016/j.phytochem.2009.03.006>.
23. Hostettmann, K.; Marston, A. *Chemistry & Pharmacology of Natural Products: Saponins* **1995**. Cambridge University Press, <https://doi.org/10.1017/CBO9780511565113>.
24. Kregiel, D.; Berlowska, J.; Witonska, I.; Antolak, H.; Proestos, C.; Babic, M.; Babic, L.; Zhang, B. Saponin-Based, Biological-Active Surfactants from Plants. In: *Application and characterization of surfactants*, Najjar, R. (Ed.), *IntechOpen* **2017**, <https://doi.org/10.5772/65591>.
25. Güçlü-Üstündağ, Ö.; Mazza, G. Saponins: Properties, Applications and Processing. *Critical reviews in food science and nutrition* **2007**, *47*, 231–258, <https://doi.org/10.1080/10408390600698197>.
26. Scognamiglio, M.; D'Abrosca, B.; Fiumano, V.; Chambery, A.; Severino, V.; Tsafantakis, N.; Pacifico, S.; Esposito, A.; Fiorentino, A. Oleanane Saponins from *Bellis Sylvestris* Cyr. and Evaluation of Their Phytotoxicity on *Aegilops Geniculata* Roth. *Phytochemistry* **2012**, *84*, 125–134, <https://doi.org/10.1016/j.phytochem.2012.08.006>.
27. Yin, X.; Hu, R.; Zhou, Y.; Zhu, W.; Zhou, Y. Cytotoxic 13,28 Epoxy Bridged Oleanane-Type Triterpenoid Saponins from the Roots of *Ardisia Crispula*. *Molecules* **2022**, *27*, 1061, <https://doi.org/10.3390/molecules27031061>.
28. Fouedjou, R.T.; Ponou, B.K.; Teponno, R.B.; Melzig, M.; Tanaka, C.; Miyamoto, T.; Tapondjou, L.A. Two New Triterpenoid Saponins: Telephiifoliosides A and B from the Roots of *Corrigiola Litoralis* Subsp. *Telephiifolia* (Pourr.) Briq. *Natural Product Research* **2022**, <https://doi.org/10.1080/14786419.2021.1914030>.
29. Lei, Y.; Shi, S.-P.; Song, Y.-L.; Bi, D.; Tu, P.-F. Triterpene Saponins from the Roots of *Ilex Asprella*. *Chem Biodivers* **2014**, *11*, 767–775, <https://doi.org/10.1002/cbdv.201300155>.
30. Ye, T.; Wang, X.; Zhang, X.; Zhang, M.; Zhang, Y. Saponin from *Tupistra Chinensis* Bak Inhibits NF-KB Signaling in Sarcoma S-180 Cell Mouse Xenografts. *Current Medical Science* **2018**, *38*, 697–703, <https://doi.org/10.1007/s11596-018-1933-y>.
31. Huang, W.; Zhang, H.; Zou, K.; Chen, J.; Li, X.; Liu, C.; Huang, N. Total Saponins of *Tupistra Chinensis* Induces Apoptosis in A549 Cells. *Neoplasma* **2012**, *59*, 613–621, https://doi.org/10.4149/neo_2012_078.
32. Xu, J.; Wang, Z.; Huang, Y.; Wang, Y.; Xiang, L.; He, X. A Spirostanol Saponin Isolated from *Tupistra Chinensis* Baker Simultaneously Induces Apoptosis and Autophagy by Regulating the JNK Pathway in Human Gastric Cancer Cells. *Steroids* **2020**, *164*, 108737, <https://doi.org/10.1016/j.steroids.2020.108737>.
33. Li, Y.-Z.; Song, B.; Zheng, X.-D.; Huang, W.-L.; Zhang, H.-W.; Jiang, Y.; Yue, Z.-G.; Song, X.-M.; Liu, J.-L. Five New Polyhydroxylated Furostanol Saponins from the Rhizomes of *Tupistra Chinensis*. *Chinese Journal of Natural Medicines* **2019**, *17*, 624–630, [https://doi.org/10.1016/S1875-5364\(19\)30065-2](https://doi.org/10.1016/S1875-5364(19)30065-2).
34. Liu, C.-X.; Guo, Z.-Y.; Xue, Y.-H.; Cheng, J.; Huang, N.-Y.; Zhou, Y.; Cheng, F.; Zou, K. Five New Furostanol Saponins from the Rhizomes of *Tupistra Chinensis*. *Fitoterapia* **2012**, *83*, 323–328, <https://doi.org/10.1016/j.fitote.2011.11.010>.

35. Vo, T.N.; Nguyen, P.L.; Tuong, L.T.; Pratt, L.M.; Vo, P.N.; Nguyen, K.P.P.; Nguyen, N.S. Lignans and Triterpenes from the Root of *Pseuderanthemum Carruthersii* Var. *Atropurpureum*. *Chem Pharm Bull (Tokyo)* **2012**, *60*, 1125–1133, <https://doi.org/10.1248/cpb.c12-00222>.
36. Pérez, A.J.; Calle, J.M.; Simonet, A.M.; Guerra, J.O.; Stochmal, A.; Macías, F.A. Bioactive Steroidal Saponins from *Agave Offoyana* Flowers. *Phytochemistry* **2013**, *95*, 298–307, <https://doi.org/10.1016/j.phytochem.2013.06.020>.
37. Yokosuka, A.; Sekiguchi, A.; Mimaki, Y. Chemical Constituents of the Leaves of *Dracaena Thaloides*. *Nat Prod Commun* **2013**, *8*, 315–318.
38. Luo, Y.; Shen, H.-Y.; Zuo, W.-J.; Wang, H.; Mei, W.-L.; Dai, H.-F. A New Steroidal Saponin from Dragon's Blood of *Dracaena Cambodiana*. *J Asian Nat Prod Res* **2015**, *17*, 409–414, <https://doi.org/10.1080/10286020.2014.967229>.
39. Diab, Y.; Ioannou, E.; Emam, A.; Vagias, C.; Roussis, V. Desmettianosides A and B, Bisdesmosidic Furostanol Saponins with Molluscicidal Activity from *Yucca Desmettiana*. *Steroids* **2012**, *77*, 686–690, <https://doi.org/10.1016/j.steroids.2012.02.014>.
40. Zhang, Y.; Yang, C.; Zhang, Y. New Steroidal Saponins from the Leaves of *Yucca Elephantipes*. *Helvetica Chimica Acta* **2013**, *96*, 1807–1813, <https://doi.org/10.1002/hlca.201200586>.
41. Yokosuka, A.; Suzuki, T.; Tatsuno, S.; Mimaki, Y. Steroidal Glycosides from the Underground Parts of *Yucca Glauca* and Their Cytotoxic Activities. *Phytochemistry* **2014**, *101*, 109–115, <https://doi.org/10.1016/j.phytochem.2014.02.002>.
42. Qu, L.; Wang, J.; Ruan, J.; Yao, X.; Huang, P.; Wang, Y.; Yu, H.; Han, L.; Zhang, Y.; Wang, T. Spirostane-Type Saponins Obtained from *Yucca Schidigera*. *Molecules* **2018**, *23*, 167, <https://doi.org/10.3390/molecules23010167>.
43. Li, S.; Zhao, J.; Liu, Y.; Chen, Z.; Xu, Q.; Khan, I.A.; Yang, S. New Triterpenoid Saponins from *Ilex Cornuta* and Their Protective Effects against H₂O₂-Induced Myocardial Cell Injury. *J Agric Food Chem* **2014**, *62*, 488–496, <https://doi.org/10.1021/jf4046667>.
44. Zuo, W.-J.; Dai, H.-F.; Zeng, Y.-B.; Wang, H.; Chen, H.-Q.; Wang, J.-H. Two New Triterpenoid Saponins from the Leaves of *Ilex Kudingcha*. *J Asian Nat Prod Res* **2012**, *14*, 308–313, <https://doi.org/10.1080/10286020.2011.653347>.
45. Bi, L.; Tian, X.; Dou, F.; Hong, L.; Tang, H.; Wang, S. New Antioxidant and Antiglycation Active Triterpenoid Saponins from the Root Bark of *Aralia Taibaiensis*. *Fitoterapia* **2012**, *83*, 234–240, <https://doi.org/10.1016/j.fitote.2011.11.002>.
46. Vassallo, A.; Pesca, M.; Ambrosio, L.; Malafronte, N.; Melle, N.D.; Dal Piaz, F.; Severino, L. Antiproliferative Oleanane Saponins from *Dizygotheca Elegantissima*. *Nat Prod Commun* **2012**, *7*, 1427–1430.
47. Tabopda, T.K.; Mitaine-Offer, A.-C.; Miyamoto, T.; Tanaka, C.; Mirjolet, J.-F.; Duchamp, O.; Ngadjui, B.T.; Lacaille-Dubois, M.-A. Triterpenoid Saponins from *Hydrocotyle Bonariensis* Lam. *Phytochemistry* **2012**, *73*, 142–147, <https://doi.org/10.1016/j.phytochem.2011.08.027>.
48. Yoshizaki, K.; Devkota, H.P.; Fujino, H.; Yahara, S. Saponins Composition of Rhizomes, Taproots, and Lateral Roots of Satsuma-Ninjin (*Panax Japonicus*). *Chem Pharm Bull (Tokyo)* **2013**, *61*, 344–350, <https://doi.org/10.1248/cpb.c12-00764>.
49. Qu, Z.-Y.; Wang, H.-C.; Jin, Y.-P.; Li, Y.-L.; Wang, Y.-P. Isolation, Identification, and Quantification of Triterpene Saponins in the Fresh Fruits of *Panax Notoginseng*. *Nat Prod Res* **2021**, <https://doi.org/10.1080/14786419.2021.1938038>.
50. Xu, J.-L.; Gu, L.-H.; Wang, Z.-T.; Bligh, A.; Han, Z.-Z.; Liu, S.-J. Seventeen Steroids from the Pith of *Tetrapanax Papyriferus*. *J Asian Nat Prod Res* **2016**, *18*, 1131–1137, <https://doi.org/10.1080/10286020.2016.1196194>.
51. Han, F.-Y.; Song, X.-Y.; Chen, J.-J.; Yao, G.-D.; Song, S.-J. Timosaponin AIII: A Novel Potential Anti-Tumor Compound from *Anemarrhena Asphodeloidea*. *Steroids* **2018**, *140*, 125–130, <https://doi.org/10.1016/j.steroids.2018.09.014>.
52. Shen, H.-Y.; Zuo, W.-J.; Wang, H.; Zhao, Y.-X.; Guo, Z.-K.; Luo, Y.; Li, X.-N.; Dai, H.-F.; Mei, W.-L. Steroidal Saponins from Dragon's Blood of *Dracaena Cambodiana*. *Fitoterapia* **2014**, *94*, 94–101, <https://doi.org/10.1016/j.fitote.2014.01.020>.

53. Rezgui, A.; Mitaine-Offer, A.-C.; Miyamoto, T.; Tanaka, C.; Lacaille-Dubois, M.-A. Spirostane-Type Saponins from *Dracaena Fragrans* “Yellow Coast”. *Nat. Prod. Commun.* **2015**, *10*, 37–38, <https://doi.org/10.1177%2F1934578X1501000111>.
54. Teponno, R.B.; Dzoyem, J.P.; Nono, R.N.; Kauhl, U.; Sandjo, L.P.; Tapondjou, L.A.; Bakowsky, U.; Opatz, T. Cytotoxicity of Secondary Metabolites from *Dracaena Viridiflora* Engl & Krause and Their Semisynthetic Analogues. *Rec. Nat. Prod.* **2017**, *11*, 421–430, <https://doi.org/10.25135/rnp.54.17.03.050>.
55. Rezgui, A.; Mitaine-Offer, A.-C.; Pertuit, D.; Miyamoto, T.; Tanaka, C.; Delemasure, S.; Dutartre, P.; Lacaille-Dubois, M.-A. Steroidal Saponins from *Dracaena Marginata*. *Nat. Prod. Commun.* **2013**, *8*, 157–160.
56. Raslan, M.A.; Melek, F.R.; Said, A.A.; Elshamy, A.I.; Umeyama, A.; Mounier, M.M. New Cytotoxic Dihydrochalcone and Steroidal Saponins from the Aerial Parts of *Sansevieria Cylindrica* Bojer Ex Hook. *Phytochemistry Letters* **2017**, *22*, 39–43, <https://doi.org/10.1016/j.phytol.2017.08.004>.
57. Tchegnitegni, B.T.; Teponno, R.B.; Jenett-Siems, K.; Melzig, M.F.; Miyamoto, T.; Tapondjou, L.A. A Dihydrochalcone Derivative and Further Steroidal Saponins from *Sansevieria Trifasciata* Prain. *Z. Naturforsch. C J Biosci.* **2017**, *72*, 477–482, <https://doi.org/10.1515/znc-2017-0027>.
58. Song, X.; Li, Y.; Zhang, D.; Jiang, Y.; Wang, W.; Song, B.; Tang, Z.; Cui, J.; Yue, Z. Two New Spirostanol Saponins from the Roots and Rhizomes of *Tupistra Chinensis*. *Phytochemistry Letters* **2015**, *13*, 6–10, <https://doi.org/10.1016/j.phytol.2015.05.004>.
59. Chabani, S.; Lavaud, C.; Benkhaled, M.; Harakat, D.; Long, C.; Haba, H. Three New Oleanane-Type Triterpene Saponins from *Atractylis Flava*. *Phytochemistry Letters* **2016**, *15*, 88–93, <https://doi.org/10.1016/j.phytol.2015.11.017>.
60. Kim, Y.A.; Kong, C.-S.; Lee, J.I.; Kim, H.; Park, H.Y.; Lee, H.-S.; Lee, C.; Seo, Y. Evaluation of Novel Antioxidant Triterpenoid Saponins from the Halophyte *Salicornia Herbacea*. *Bioorg Med Chem Lett* **2012**, *22*, 4318–4322, <https://doi.org/10.1016/j.bmcl.2012.05.017>.
61. Arslan, I.; Celik, A.; Chol, J.H. A Cytotoxic Triterpenoid Saponin from Under-Ground Parts of *Gypsophila Pilulifera* Boiss.& Heldr. *Fitoterapia* **2012**, *83*, 699–703, <https://doi.org/10.1016/j.fitote.2012.02.005>.
62. Manase, M.J.; Mitaine-Offer, A.-C.; Miyamoto, T.; Tanaka, C.; Delemasure, S.; Dutartre, P.; Lacaille-Dubois, M.-A. Triterpenoid Saponins from *Polycarpa Corymbosa* Lamk. Var. *Eriantha* Hochst. *Phytochemistry* **2014**, *100*, 150–155, <https://doi.org/10.1016/j.phytochem.2013.12.005>.
63. Xu, W.; Fang, J.; Zhu, Z.; Wu, J.; Li, Y. A New Triterpenoid Saponin from the Roots of *Silene Viscidula*. *Natural Product Research* **2012**, *26*, 2002–2007, <https://doi.org/10.1080/14786419.2011.637216>.
64. Abaci, H.; Akagac, G.; Nalbantsoy, A.; Sarikahya, N.B. A Hederagenin-Type Triterpene Saponin, Sumbulianoside a from *Cephalaria Sumbuliana* and Its Potent Immunomodulatory Activity against Seasonal Flu Virus H3N2. *Natural Product Research* **2022**, *36*, 2495–2503, <https://doi.org/10.1080/14786419.2021.1910691>.
65. Dong J.-L. Triterpenoids isolated from flower buds of *Lonicera macranthoides*. *Chinese Traditional and Herbal Drugs* **2018**, *24*, 4484–4490.
66. Chen, Y.; Shan, Y.; Zhao, Y.Y.; Wang, Q.Z.; Wang, M.; Feng, X.; Liang, J.Y. Two New Triterpenoid Saponins from *Lonicera Macranthoides*. *Chinese Chemical Letters* **2012**, *23*, 325–328, <https://doi.org/10.1016/j.cclet.2011.12.013>.
67. Gao, L.; Zhang, L.; Wang, L.-M.; Liu, J.-Y.; Cai, P.-L.; Yang, S.-L. New Triterpenoid Saponins from *Patrinia Scabiosifolia*. *J Asian Nat Prod Res* **2012**, *14*, 333–341, <https://doi.org/10.1080/10286020.2011.653685>.
68. Zhang, X.; Zou, L.-H.; He, Y.-L.; Peng, C.; Guo, L.; Xiong, L. Triterpenoid Saponins from the Buds of *Lonicera Similis*. *Natural Product Research* **2018**, *32*, 2282–2290, <https://doi.org/10.1080/14786419.2017.1408092>.
69. Yang, F.; Shi, H.; Zhang, X.; Yang, H.; Zhou, Q.; Yu, L. (Lucy) Two New Saponins from Tetraploid Jiaogulan (*Gynostemma Pentaphyllum*), and Their Anti-Inflammatory and α -Glucosidase Inhibitory Activities. *Food Chemistry* **2013**, *141*, 3606–3613, <https://doi.org/10.1016/j.foodchem.2013.06.015>.
70. Lou, Y.-Y.; Zheng, X.; Huang, Y.-P.; Mu, L.; Zhang, X.-G.; Zhao, Z.-W.; Song, Z.; Zhang, J.; Yin, Z.-Q.; Pan, K. New Dammarane-Type Triterpenoid Saponins from *Gynostemma Pentaphyllum* and Their Sirt1 Agonist Activity. *Bioorganic Chemistry* **2021**, *116*, 105357, <https://doi.org/10.1016/j.bioorg.2021.105357>.
71. Tapondjou, L.A.; Jenett-Siems, K.; Böttger, S.; Melzig, M.F. Steroidal Saponins from the Flowers of *Dioscorea Bulbifera* Var. *Sativa*. *Phytochemistry* **2013**, *95*, 341–350, <https://doi.org/10.1016/j.phytochem.2013.07.020>.

72. Zhang, L.-J.; Yu, H.-S.; Kang, L.-P.; Feng, B.; Quan, B.; Song, X.-B.; Ma, B.-P.; Kang, T.-G. Two New Steroidal Saponins from the Biotransformation Product of the Rhizomes of *Dioscorea Nipponica*. *J Asian Nat Prod Res* **2012**, *14*, 640–646, <https://doi.org/10.1080/10286020.2012.682155>.
73. Zheng, L.; Zhou, Y.; Zhang, J.-Y.; Song, M.; Yuan, Y.; Xiao, Y.-J.; Xiang, T. Two New Steroidal Saponins from the Rhizomes of *Dioscorea Zingiberensis*. *Chin J Nat Med* **2014**, *12*, 142–147, [https://doi.org/10.1016/S1875-5364\(14\)60023-6](https://doi.org/10.1016/S1875-5364(14)60023-6).
74. Tabopda, T.K.; Mitaine-Offer, A.-C.; Tanaka, C.; Miyamoto, T.; Mirjolet, J.-F.; Duchamp, O.; Ngadjui, B.T.; Lacaille-Dubois, M.-A. Steroidal Saponins from *Dioscorea Preussii*. *Fitoterapia* **2014**, *97*, 198–203, <https://doi.org/10.1016/j.fitote.2014.06.006>.
75. Xiao, Z.-H.; Wang, F.-Z.; Sun, A.-J.; Li, C.-R.; Huang, C.-G.; Zhang, S. A New Triterpenoid Saponin from *Abrus Precatorius* Linn. *Molecules* **2011**, *17*, 295–302, <https://doi.org/10.3390/molecules17010295>.
76. Yokosuka, A.; Koyama, Y.; Mimaki, Y. Chemical Constituents of the Underground Parts of *Iris Florentina* and Their Cytotoxic Activity. *Nat Prod Commun* **2015**, *10*, 955–958, <https://doi.org/10.1177%2F1934578X1501000641>.
77. Lanzotti, V.; Romano, A.; Lanzuise, S.; Bonanomi, G.; Scala, F. Antifungal Saponins from Bulbs of White Onion, *Allium Cepa* L. *Phytochemistry* **2012**, *74*, 133–139, <https://doi.org/10.1016/j.phytochem.2011.11.008>.
78. Fang, Y.-S.; Cai, L.; Li, Y.; Wang, J.-P.; Xiao, H.; Ding, Z.-T. Spirostanol Steroids from the Roots of *Allium Tuberosum*. *Steroids* **2015**, *100*, 1–4, <https://doi.org/10.1016/j.steroids.2015.03.015>.
79. Matsuo, Y.; Akagi, N.; Hashimoto, C.; Tachikawa, F.; Mimaki, Y. Steroidal Glycosides from the Bulbs of *Bessera Elegans* and Their Cytotoxic Activities. *Phytochemistry* **2013**, *96*, 244–256, <https://doi.org/10.1016/j.phytochem.2013.09.023>.
80. Yokosuka, A.; Takagi, K.; Mimaki, Y. New Cholestanol Glycosides and Sterols from the Underground Parts of *Chamaelirium Luteum* and Their Cytotoxic Activity. *J Nat Med* **2013**, *67*, 590–598, <https://doi.org/10.1007/s11418-012-0718-z>.
81. Park, B.K.; So, K.S.; Ko, H.J.; Kim, H.J.; Kwon, K.S.; Kwon, Y.S.; Son, K.H.; Kwon, S.Y.; Kim, H.P. Therapeutic Potential of the Rhizomes of *Anemarrhena Asphodeloides* and Timosaponin A-III in an Animal Model of Lipopolysaccharide-Induced Lung Inflammation. *Biomol Ther (Seoul)* **2018**, *26*, 553–559, <https://doi.org/10.4062/biomolther.2017.249>.
82. Pan, Z.-H.; Li, Y.; Liu, J.-L.; Ning, D.-S.; Li, D.-P.; Wu, X.-D.; Wen, Y.-X. A Cytotoxic Cardenolide and a Saponin from the Rhizomes of *Tupistra Chinensis*. *Fitoterapia* **2012**, *83*, 1489–1493, <https://doi.org/10.1016/j.fitote.2012.08.015>.
83. Xiao, Y.-H.; Yin, H.-L.; Chen, L.; Tian, Y.; Liu, S.-J.; Zhang, G.-J.; Chen, H.-W.; Jin, H.; Li, B.; Dong, J.-X. Three Spirostanol Saponins and a Flavane-O-Glucoside from the Fresh Rhizomes of *Tupistra Chinensis*. *Fitoterapia* **2015**, *102*, 102–108, <https://doi.org/10.1016/j.fitote.2015.02.008>.
84. Wei, L.-M.; Wu, Y.-C.; Chen, C.-C.; Hsieh, P.-W.; Pan, W.-B. Tupichinins B-D, Three New Spirostanol Saponins from *Tupistra Chinensis* Rhizomes. *Nat Prod Res* **2014**, *28*, 74–80, <https://doi.org/10.1080/14786419.2013.838240>.
85. Liu, C.; Guo, Z.; Deng, Z.; Xue, Y.; Zou, K.; Zhou, Y.; Huang, N.; Cheng, F. New Furostanol Saponins from the Rhizomes of *Tupistra Chinensis*. *Nat Prod Res* **2013**, *27*, 123–129, <https://doi.org/10.1080/14786419.2012.660637>.
86. Liu, C.-X.; Guo, Z.; Xue, Y.-H.; Zhang, H.-Y.; Zhang, H.-Q.; Zou, K.; Huang, N.-Y. Tupisteroide A-C, Three New Polyhydroxylated Steroidal Constituents from the Roots of *Tupistra Chinensis*. *Magn Reson Chem* **2012**, *50*, 320–324, <https://doi.org/10.1002/mrc.2861>.
87. Xiang, L.; Wang, Y.; Yi, X.; Zheng, G.; He, X. Bioactive Spirostanol Saponins from the Rhizome of *Tupistra Chinensis*. *Steroids* **2016**, *108*, 39–46, <https://doi.org/10.1016/j.steroids.2016.02.012>.
88. Cui, Y.; Yang, X.; Zhang, D.; Li, Y.; Zhang, L.; Song, B.; Yue, Z.; Song, X.; Tang, H. Steroidal Constituents from Roots and Rhizomes of *Smilacina Japonica*. *Molecules* **2018**, *23*, 798, <https://doi.org/10.3390/molecules23040798>.
89. Zhang, X.-D.; Chen, C.-X.; Yang, J.-Y.; Ni, W.; Liu, H.-Y. New Minor Spirostanol Glycosides from *Ypsilandra Thibetica*. *Helvetica Chimica Acta* **2012**, *95*, 1087–1093, <https://doi.org/10.1002/hlca.201100368>.
90. Liu, Y.; Tian, X.; Hua, D.; Cheng, G.; Wang, K.; Zhang, L.; Tang, H.; Wang, M. New Steroidal Saponins from the Rhizomes of *Paris Delavayi* and Their Cytotoxicity. *Fitoterapia* **2016**, *111*, 130–137, <https://doi.org/10.1016/j.fitote.2016.04.018>.

91. Yan, H.; Ni, W.; Yu, L.-L.; Xiao, L.-G.; Ji, Y.-H.; Liu, H.-Y. Parisvaniosides A–E, Five New Steroidal Saponins from *Paris Vaniotii*. *Steroids* **2022**, *177*, 108949, <https://doi.org/10.1016/j.steroids.2021.108949>.
92. Toukea, D.D.; Kamto, E.L.D.; Simo, L.M.; Mbing, J.N.; Antheaume, C.; Haddad, M.; Noté, O.P.; Pegnyemb, D.E. New Triterpenoid Saponin from the Stems of *Albizia Adianthifolia* (Schumach.) W.Wight. *Nat Prod Res* **2022**, *36*, 780–788, <https://doi.org/10.1080/14786419.2020.1805604>.
93. Ndontsa, B.L.; Tchinda, A.; Teponno, R.B.; Mpetga, J.S.; Frédéric, M.; Tane, P. Ardisikivuosome, A New Triterpenoid Saponin from *Ardisia Kivuensis* (Myrsinaceae). *Natural Product Communications* **2012**, *7*, <https://doi.org/10.1177/1934578X1200700425>.
94. Carpinteyro Díaz, A.E.; Herfindal, L.; Rathe, B.A.; Sletta, K.Y.; Vedeler, A.; Haavik, S.; Fossen, T. Cytotoxic Saponins and Other Natural Products from Flowering Tops of *Narthecium Ossifragum* L. *Phytochemistry* **2019**, *164*, 67–77, <https://doi.org/10.1016/j.phytochem.2019.04.014>.
95. Linnek, J.; Mitaine-Offer, A.-C.; Paululat, T.; Lacaille-Dubois, M.-A. Two New Triterpenoid Saponins from *Pittosporum Senacia* Putterlick (Pittosporaceae). *Magn Reson Chem* **2012**, *50*, 798–802, <https://doi.org/10.1002/mrc.3876>.
96. Betina-Bencharif, S. Isolement et Caractérisation de Saponosides Extraits de Deux Plantes Médicinales : *Cyclamen Africanum*, *Zygophyllum Cornutum* et Évaluation de Leur Activité Anti-Inflammatoire. Thèse de doctorat **2014**, Médecine humaine et pathologie, Université de Bourgogne - Université Mentouri-Constantine, France.
97. Zhang, Q.; Lu, Y.-Y.; Yang, L.; Tang, H.-F. New Triterpenoid Saponins from the Whole Plants of *Clematis Heracleifolia*. *Fitoterapia* **2022**, *159*, 105179, <https://doi.org/10.1016/j.fitote.2022.105179>.
98. Li, Y.-Z.; Zhang, H.-W.; Fan, H.; Liang, X.-F.; Song, B.; Chen, H.; Huang, W.-L.; Yue, Z.-G.; Song, X.-M.; Liu, J.-L. Steroidal Constituents from *Helleborus Thibetanus* and Their Cytotoxicities. *Chinese Journal of Natural Medicines* **2019**, *17*, 778–784, [https://doi.org/10.1016/s1875-5364\(19\)30094-9](https://doi.org/10.1016/s1875-5364(19)30094-9).
99. Watanabe, K.; Mimaki, Y.; Fukaya, H.; Matsuo, Y. Cycloartane and Oleanane Glycosides from the Tubers of *Eranthis Cilicica*. *Molecules* **2018**, *24*, 69, <https://doi.org/10.3390/molecules24010069>.
100. Erst, A.S.; Sukhorukov, A.P.; Mitrenina, E.Y. et al. An Integrative Taxonomic Approach Reveals a New Species of *Eranthis* (Ranunculaceae) in North Asia. *PhytoKeys* **2020**, *140*, 75–100, <https://doi.org/10.3897/phytokeys.140.49048>.
101. Zhang, P.-Y.; Qin, S.-H.; Zhao, H.-X.; Wang, F.-L.; Guo, H.-J.; Bai, H. A New Triterpenoid Saponin from *Sanguisorba Officinalis*. *J Asian Nat Prod Res* **2012**, *14*, 607–611, <https://doi.org/10.1080/10286020.2012.674944>.
102. Wang, J.; Lu, J.; Lv, C.; Xu, T.; Jia, L. Three New Triterpenoid Saponins from Root of *Gardenia Jasminoides* Ellis. *Fitoterapia* **2012**, *83*, 1396–1401, <https://doi.org/10.1016/j.fitote.2012.07.004>.
103. Cui, H.; Xiao, H.; Ran, X.-K.; Li, Y.-Y.; Dou, D.-Q.; Kang, T.-G. Two New Oleanane-Type Pentacyclic Triterpenoid Saponins from the Husks of *Xanthoceras Sorbifolia* Bunge. *J Asian Nat Prod Res* **2012**, *14*, 216–223, <https://doi.org/10.1080/10286020.2011.641954>.
104. Manase, M.J.; Mitaine-Offer, A.-C.; Pertuit, D.; Miyamoto, T.; Tanaka, C.; Delemasure, S.; Dutartre, P.; Mirjolet, J.-F.; Duchamp, O.; Lacaille-Dubois, M.-A. *Solanum Incanum* and *S. Heteracanthum* as Sources of Biologically Active Steroid Glycosides: Confirmation of Their Synonymy. *Fitoterapia* **2012**, *83*, 1115–1119, <https://doi.org/10.1016/j.fitote.2012.04.024>.
105. Chen, F.-F.; Zhou, J.; Zhang, Y.-W.; Chen, Y.-P.; Wang, Y.-R.; Zhao, Y.-F.; Liu, W.; Huang, X.-F. Five New Steroidal Saponins from the Seeds of *Solanum Melongena* L. *Phytochemistry Letters* **2021**, *41*, 21–26, <https://doi.org/10.1016/j.phytol.2020.10.008>.
106. Xu, Z.-P.; Liu, Y.; Wang, S.-Y.; Li, Z.-W.; Li, X.-M.; Lu, D.-X.; Pan, J.; Kuang, H.-X.; Yang, B.-Y. Eight Undescribed Steroidal Saponins Including an Unprecedented 16, 26-Epoxy-Furostanol Saponin from *Solanum Xanthocarpum* and Their Cytotoxic Activities. *Phytochemistry* **2022**, *199*, 113171, <https://doi.org/10.1016/j.phytochem.2022.113171>.
107. Xu, Z.-P.; Liu, Y.; Wang, S.-Y.; Li, X.-M.; Lu, D.-X.; Li, Z.-W.; Pan, J.; Kuang, H.-X.; Yang, B.-Y. Cholestanol Saponins A-F, Six New Rare Cholestanol Saponins Including Two Unprecedented 14-Methyl C28 Cholestanol Saponins from *Solanum Xanthocarpum*. *Tetrahedron* **2022**, *109*, 132674, <https://doi.org/10.1016/j.tet.2022.132674>.
108. Di, T.-M.; Yang, S.-L.; Du, F.-Y.; Zhao, L.; Li, X.-H.; Xia, T.; Zhang, X.-F. Oleiferasaponin A2, a Novel Saponin from *Camellia Oleifera* Abel. Seeds, Inhibits Lipid Accumulation of HepG2 Cells Through Regulating Fatty Acid Metabolism. *Molecules* **2018**, *23*, 3296, <https://doi.org/10.3390/molecules23123296>.

109. Waheed, A.; Barker, J.; Barton, S.J.; Owen, C.P.; Ahmed, S.; Carew, M.A. A Novel Steroidal Saponin Glycoside from *Fagonia Indica* Induces Cell-Selective Apoptosis or Necrosis in Cancer Cells. *Eur J Pharm Sci* **2012**, *47*, 464–473, <https://doi.org/10.1016/j.ejps.2012.07.004>.
110. Wang, Z.-F.; Wang, B.-B.; Zhao, Y.; Wang, F.-X.; Sun, Y.; Guo, R.-J.; Song, X.-B.; Xin, H.-L.; Sun, X.-G. Furostanol and Spirostanol Saponins from *Tribulus Terrestris*. *Molecules* **2016**, *21*, 429, <https://doi.org/10.3390/molecules21040429>.
111. Kang, L.-P.; Wu, K.-L.; Yu, H.-S. et al. Steroidal Saponins from *Tribulus Terrestris*. *Phytochemistry* **2014**, *107*, 182–189, <https://doi.org/10.1016/j.phytochem.2014.08.003>.
112. Juang, Y.-P.; Liang, P.-H. Biological and Pharmacological Effects of Synthetic Saponins. *Molecules* **2020**, *25*, 4974, <https://doi.org/10.3390/molecules25214974>.
113. Xia, L.; Guo, Q.; Zhang, S.-Y.; Liang, Y.-S.; Yao, W.-L.; Zhang, X.-T. Research progress of *Ypsilandra thibetica*, a medicinal plant of Liliaceae. *Zhongguo Zhong Yao Za Zhi* **2013**, *38*, 3413–3418.
114. Abebe, H.; Gebre, T.; Haile, A. Phytochemical Investigation on the Roots of *Solanum Incanum*, Hadiya Zone, Ethiopia. *J. Med. Plants Stud.* **2014**, *2*, 83–93.
115. Ali, K.; Khan, H. *Fagonia Indica*; A Review on Chemical Constituents, Traditional Uses and Pharmacological Activities. *Curr Pharm Des* **2021**, *27*, 2648–2660, <https://doi.org/10.2174/138161282666201210105941>.
116. Pastorino, G.; Cornara, L.; Soares, S.; Rodrigues, F.; Oliveira, M.B.P.P. Liquorice (*Glycyrrhiza Glabra*): A Phytochemical and Pharmacological Review. *Phytother Res* **2018**, *32*, 2323–2339, <https://doi.org/10.1002/ptr.6178>.
117. Ur Rahman, S.; Ismail, M.; Khurram, M.; Ullah, I.; Rabbi, F.; Iriti, M. Bioactive Steroids and Saponins of the Genus *Trillium*. *Molecules* **2017**, *22*, 2156, <https://doi.org/10.3390/molecules22122156>.
118. Chrząszcz, M.; Krzemińska, B.; Celiński, R.; Szewczyk, K. Phenolic Composition and Antioxidant Activity of Plants Belonging to the *Cephalaria* (Caprifoliaceae) Genus. *Plants (Basel)* **2021**, *10*, 952, <https://doi.org/10.3390/plants10050952>.
119. Sbhatu, D.B.; Abraha, H.B. Preliminary Antimicrobial Profile of *Solanum Incanum* L.: A Common Medicinal Plant. *Evid Based Complement Alternat Med* **2020**, *2020*, 3647065, <https://doi.org/10.1155/2020/3647065>.
120. Thu, Z.M.; Oo, S.M.; Nwe, T.M.; Aung, H.T.; Armijos, C.; Hussain, F.H.S.; Vidari, G. Structures and Bioactivities of Steroidal Saponins Isolated from the Genera *Dracaena* and *Sansevieria*. *Molecules* **2021**, *26*, 1916, <https://doi.org/10.3390/molecules26071916>.
121. Patel, S. *Yucca*: A Medicinally Significant Genus with Manifold Therapeutic Attributes. *Nat. Prod. Bioprospect.* **2012**, *2*, 231–234, <https://doi.org/10.1007/s13659-012-0090-4>.
122. Zhang, Y.; Zhang, Y.-J.; Jacob, M.R.; Li, X.-C.; Yang, C.-R. Steroidal Saponins from the Stem of *Yucca Elephantipes*. *Phytochemistry* **2008**, *69*, 264–270, <https://doi.org/10.1016/j.phytochem.2007.06.015>.
123. Oh, J.-H.; Jeong, Y.J.; Koo, H.J.; Park, D.W.; Kang, S.C.; Khoa, H.V.B.; Le, L.B.; Cho, J.H.; Lee, J.-Y. Antimicrobial Activities against Periodontopathic Bacteria of *Pittosporum Tobira* and Its Active Compound. *Molecules* **2014**, *19*, 3607–3616, <https://doi.org/10.3390/molecules19033607>.
124. Lacaille-Dubois, M.-A. Bioactive Saponins with Cancer Related and Immunomodulatory Activity: Recent Developments. In: Atta-ur-Rahman, Ed. - *Studies in Natural Products Chemistry. Bioactive Natural Products (Part L)* **2005**, Elsevier, *32*, 209–246, [https://doi.org/10.1016/S1572-5995\(05\)80057-2](https://doi.org/10.1016/S1572-5995(05)80057-2).
125. Ma, Q.; Jiang, J.-G.; Yuan, X.; Qiu, K.; Zhu, W. Comparative Antitumor and Anti-Inflammatory Effects of Flavonoids, Saponins, Polysaccharides, Essential Oil, Coumarin and Alkaloids from *Cirsium Japonicum* DC. *Food and Chemical Toxicology* **2019**, *125*, 422–429, <https://doi.org/10.1016/j.fct.2019.01.020>.
126. Wang, Z.; Xu, J.; Wang, Y.; Xiang, L.; He, X. Total Saponins from *Tupistra Chinensis* Baker Inhibits Growth of Human Gastric Cancer Cells in Vitro and in Vivo. *Journal of Ethnopharmacology* **2021**, *278*, 114323, <https://doi.org/10.1016/j.jep.2021.114323>.
127. Li, Y.; Lin, W.; Huang, J.; Xie, Y.; Ma, W. Anti-Cancer Effects of *Gynostemma Pentaphyllum* (Thunb.) Makino (Jiaogulan). *Chin Med* **2016**, *11*, 43, <https://doi.org/10.1186/s13020-016-0114-9>.
128. Wang, D.; Huo, R.; Cui, C.; Gao, Q.; Zong, J.; Wang, Y.; Sun, Y.; Hou, R. Anticancer Activity and Mechanism of Total Saponins from the Residual Seed Cake of *Camellia Oleifera* Abel. in Hepatoma-22 Tumor-Bearing Mice. *Food Funct* **2019**, *10*, 2480–2490, <https://doi.org/10.1039/c9fo00069k>.
129. Xie, W.; Meng, X.; Zhai, Y.; Zhou, P.; Ye, T.; Wang, Z.; Sun, G.; Sun, X. *Panax Notoginseng* Saponins: A Review of Its Mechanisms of Antidepressant or Anxiolytic Effects and Network Analysis on Phytochemistry and Pharmacology. *Molecules* **2018**, *23*, 940, <https://doi.org/10.3390/molecules23040940>.

- 130.Kim, M.S.; Seo, J.Y.; Oh, J.; Jang, Y.K.; Lee, C.H.; Kim, J.-S. Neuroprotective Effect of Halophyte *Salicornia Herbacea* L. Is Mediated by Activation of Heme Oxygenase-1 in Mouse Hippocampal HT22 Cells. *J Med Food* **2017**, *20*, 140–151, <https://doi.org/10.1089/jmf.2016.3829>.
- 131.Nguekeu, Y.M.M.; Ndontsa, B.L.; Mbouangouere, R.; Awouafack, M.D.; Ito, T.; Tane, P.; Morita, H. A New Alkenylmethylresorcinol from the Fruits of *Ardisia Kivuensis*. *Nat Prod Commun* **2016**, *11*, 661–662, <https://doi.org/10.1177%2F1934578X1601100527>.
- 132.Murugesu, S.; Selamat, J.; Perumal, V. Phytochemistry, Pharmacological Properties, and Recent Applications of *Ficus Benghalensis* and *Ficus Religiosa*. *Plants* **2021**, *10*, 2749, <https://doi.org/10.3390/plants10122749>.
- 133.Nazemiyeh, H.; Zengin, G.; Mehrad, H.; Farhoudi, M.; Bahadori, M.B. LC-MS/MS-Based Steroidal Saponins Profiling and Biological Activities of *Ruscus Hyrcanus* Woronow. *European Journal of Integrative Medicine* **2020**, *40*, 101245, <https://doi.org/10.1016/j.eujim.2020.101245>.
- 134.Yi, Y.-S. New Mechanisms of Ginseng Saponin-Mediated Anti-Inflammatory Action via Targeting Canonical Inflammasome Signaling Pathways. *Journal of Ethnopharmacology* **2021**, *278*, 114292, <https://doi.org/10.1016/j.jep.2021.114292>.
- 135.Shu, P.-P.; Li, L.-X.; He, Q.-M.; Pan, J.; Li, X.-L.; Zhu, M.; Yang, Y.; Qu, Y. Identification and Quantification of Oleanane Triterpenoid Saponins and Potential Analgesic and Anti-Inflammatory Activities from the Roots and Rhizomes of *Panax Stipuleanatus*. *Journal of Ginseng Research* **2021**, *45*, 305–315, <https://doi.org/10.1016/j.jgr.2020.05.002>.
- 136.Xiang, L.; Yi, X.; Wang, Y.; He, X. Antiproliferative and Anti-Inflammatory Polyhydroxylated Spirostanol Saponins from *Tupistra Chinensis*. *Sci Rep* **2016**, *6*, 31633, <https://doi.org/10.1038/srep31633>.
- 137.Cha, K.-J.; Im, M.A.; Gu, A.; Kim, D.H.; Lee, D.; Lee, J.S.; Lee, J.-S.; Kim, I.S. Inhibitory Effect of *Patrinia Scabiosifolia* Link on the Development of Atopic Dermatitis-like Lesions in Human Keratinocytes and NC/Nga Mice. *J Ethnopharmacol* **2017**, *206*, 135–143, <https://doi.org/10.1016/j.jep.2017.03.045>.
- 138.Ou-Yang, S.-H.; Jiang, T.; Zhu, L.; Yi, T. *Dioscorea Nipponica* Makino: A Systematic Review on Its Ethnobotany, Phytochemical and Pharmacological Profiles. *Chem Centr J* **2018**, *12*, 57, <https://doi.org/10.1186/s13065-018-0423-4>.
- 139.González-Madariaga, Y.; Mena-Linares, Y.; Martín-Monteagudo, D.; Valido-Díaz, A.; Guerra-de-León, J.O.; Nieto-Reyes, L. In Vivo Anti-Inflammatory Effect of Saponin-Enriched Fraction from *Agave Brittoniana* Trel Subspecie *Brachypus*. *Ars Pharmaceutica (Internet)* **2020**, *61*, 231-237, <https://dx.doi.org/10.30827/ars.v61i4.15352>.
- 140.Suresh, P.S.; Singh, P.P.; Sharma, A.; Padwad, Y.S.; Sharma, U. Steroidal Saponins of *Trillium Govarianum*: Quality Control, Pharmacokinetic Analysis, and Anti-Inflammatory Activity. *Biocatalysis and Agricultural Biotechnology* **2021**, *35*, 102071, <https://doi.org/10.1016/j.bcab.2021.102071>.
- 141.Shi, Z.-Y.; Zeng, J.-Z.; Wong, A.S.T. Chemical Structures and Pharmacological Profiles of Ginseng Saponins. *Molecules* **2019**, *24*, 2443, <https://doi.org/10.3390/molecules24132443>.
- 142.Chen, L.; Li, M.; Yang, Z.; Tao, W.; Wang, P.; Tian, X.; Li, X.; Wang, W. Gardenia Jasminoides Ellis: Ethnopharmacology, Phytochemistry, and Pharmacological and Industrial Applications of an Important Traditional Chinese Medicine. *J Ethnopharmacol* **2020**, *257*, 112829, <https://doi.org/10.1016/j.jep.2020.112829>.
- 143.Kasetti, R.B.; Maddineni, P.; Kodati, B.; Nagarajan, B.; Yacoub, S. Astragaloside IV Attenuates Ocular Hypertension in a Mouse Model of TGFβ2 Induced Primary Open Angle Glaucoma. *Int J Mol Sci* **2021**, *22*, 12508, <https://doi.org/10.3390/ijms222212508>.
- 144.Wang, Z.-F.; Wang, B.-B.; Zhao, Y.; Wang, F.-X.; Sun, Y.; Guo, R.-J.; Song, X.-B.; Xin, H.-L.; Sun, X.-G. Furostanol and Spirostanol Saponins from *Tribulus Terrestris*. *Molecules* **2016**, *21*, 429, <https://doi.org/10.3390/molecules21040429>.
- 145.Sun, A.; Xu, X.; Lin, J.; Cui, X.; Xu, R. Neuroprotection by Saponins. *Phytotherapy Research* **2015**, *29*, 187–200, <https://doi.org/10.1002/ptr.5246>.
- 146.Maroyi, A. *Albizia Adianthifolia*: Botany, Medicinal Uses, Phytochemistry, and Pharmacological Properties. *The Scientific World Journal* **2018**, *2018*, 7463584, <https://doi.org/10.1155/2018/7463584>.
- 147.Vanti, G.; Capizzi, M.; Di Cesare Mannelli, L.; Lucarini, E.; Bergonzi, M.C.; Ghelardini, C.; Bilia, A.R. Escinosomes: Safe and Successful Nanovesicles to Deliver Andrographolide by a Subcutaneous Route in a Mice Model of Oxaliplatin-Induced Neuropathy. *Pharmaceutics* **2022**, *14*, 493, <https://doi.org/10.3390/pharmaceutics14030493>.

- 148.Zheng, T.; Shu, G.; Yang, Z.; Mo, S.; Zhao, Y.; Mei, Z. Antidiabetic Effect of Total Saponins from *Entada Phaseoloides* (L.) Merr. in Type 2 Diabetic Rats. *J Ethnopharmacol* **2012**, *139*, 814–821, <https://doi.org/10.1016/j.jep.2011.12.025>.
- 149.Melakhessou, M.A.; Marref, S.E.; Benkiki, N.; Marref, C.; Becheker, I.; Khattabi, L. In Vitro, Acute and Subchronic Evaluation of the Antidiabetic Activity of *Atractylis Flava* Desf n-Butanol Extract in Alloxan-Diabetic Rats. *Future Journal of Pharmaceutical Sciences* **2021**, *7*, 206, <https://doi.org/10.1186/s43094-021-00358-5>.
- 150.Sung, J.-H.; Park, S.-H.; Seo, D.-H.; Lee, J.-H.; Hong, S.-W.; Hong, S.-S. Antioxidative and Skin-Whitening Effect of an Aqueous Extract of *Salicornia Herbacea*. *Biosci Biotechnol Biochem* **2009**, *73*, 552–556, <https://doi.org/10.1271/bbb.80601>.
- 151.Fang, Z.; Li, J.; Yang, R.; Fang, L.; Zhang, Y. A Review: The Triterpenoid Saponins and Biological Activities of *Lonicera Linn.* *Molecules* **2020**, *25*, 3773, <https://doi.org/10.3390/molecules25173773>.
- 152.Han, J.H.; Kim, M.; Choi, H.-J.; Jin, J.S.; Lee, S.-O.; Bae, S.-J.; Ryu, D.; Ha, K.-T. The Oral Administration of *Sanguisorba Officinalis* Extract Improves Physical Performance through LDHA Modulation. *Molecules* **2021**, *26*, 1579, <https://doi.org/10.3390/molecules26061579>.
- 153.de Groot, C.; Müller-Goymann, C.C. Saponin Interactions with Model Membrane Systems - Langmuir Monolayer Studies, Hemolysis and Formation of ISCOMs. *Planta Med* **2016**, *82*, 1496–1512, <https://doi.org/10.1055/s-0042-118387>.
- 154.Jeepipalli, S.P.K.; Du, B.; Sabitaliyevich, U.Y.; Xu, B. New Insights into Potential Nutritional Effects of Dietary Saponins in Protecting against the Development of Obesity. *Food Chem* **2020**, *318*, 126474, <https://doi.org/10.1016/j.foodchem.2020.126474>.
- 155.Juszczak, M.; Kluska, M.; Skalski, B.; Źuchowski, J.; Stochmal, A.; Olas, B.; Woźniak, K. Multidirectional Effects of Saponin Fraction Isolated from the Leaves of Sea Buckthorn *Elaeagnus Rhamnoides* (L.) A. Nelson. *Biomedicine & Pharmacotherapy* **2021**, *137*, 111395, <https://doi.org/10.1016/j.biopha.2021.111395>.
- 156.FAO Utilisations- Année Internationale Du Quinoa 2013 Available online: https://www.fao.org/quinoa-2013/en/?no_mobile=1 (accessed on 24 May 2022).