Review

Research progress on chemical constituents and pharmacological effects of medicinal plant *Scutellaria baicalensis*

Yunpeng Yang, Ruiqi Ma, Yuzheng Xiang, Yu Wang, Rui Liu, Ying Li*, Yu Chen*

School of Life Science and Biopharmaceutics, Shenyang Pharmaceutical University, Shenyang 110016, China

Abstract

***Scutellaria baicalensis* (*S. baicalensis*) is a heat-clearing and moisture-drying medicine, which is used to treat diseases such as warm fever, upper respiratory tract infection, lung heat cough, moist heat jaundice, pneumonia, dysentery, hemoptysis, red eyes, restless fetus, hypertension, abscess, swelling and boils. In recent years, with the in-depth study of its chemical composition and pharmacological activity, it was found that the clinical antibacterial activity of *S. baicalensis* was significant, and it did not produce drug resistance. The chemical constituents and pharmacological effects of *S. baicalensis* were reviewed in this paper. This review can provide reference for further development and utilization of medicinal value of *S. baicalensis*.**

Keywords: *Scutellaria baicalensis*; chemical composition; pharmacological effect

1 Introduction

Scutellaria baicalensis was originally recorded in Shennong's Herbal Classic [1] and was listed as a medium product. In the Compendium of Materia Medica, *S. baicalensis* was classified as the mountain grass. *S. baicalensis* is quite widely distributed, and its real origin is difficult to determine. In ancient times, *S. baicalensis* was distributed in Hubei, Henan, Shandong, Jiangsu, Shaanxi, Gansu, Shanxi and other provinces. In modern times, the main producing areas of *S. baicalensis* moved to the northeast, north and northwest regions, and *S. baicalensis* from Rehe (Chengde, Hebei Province) is regarded as modern authentic medicinal material [2]. *S. baicalensis* has high medicinal value in traditional medical classics, such as "Shennong Materia Medica", "Treatise on Febrile Diseases" and "Compendium of Materia Medica". It can be used to treat chest tightness, cough, abdominal pain, diarrhea, inflammation, bleeding, restless birth and so on [3]. According to *Chinese Pharmacopoeia* (2025 edition), *S. baicalensis* is bitter in taste and cold in nature. It enters the lung, gallbladder, spleen, large intestine and small intestine meridians. It has the effect of pacifying liver fire, clearing heat and

* Author to whom correspondence should be addressed. Address: School of Life Science and Biopharmaceutics, Shenyang Pharmaceutical University, Shenyang 110016, China; Tel.: +86-18341400530 (Yu Chen), +86-18341400610 (Ying Li); E-mail: gzweishengwu@126.com (Yu Chen), yyswalk@163.com (Ying Li).
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toxins, as well as arresting bleeding and stablizing the fetus [4].

With the improvement of modern chemical analysis technology and pharmacological activity evaluation methods, the research of *S. baicalensis* has been made progress. In this paper, the chemical constituents and pharmacological effects of *S. baicalensis* were reviewed in order to provide reference for further research and development of *S. baicalensis.*

2 Chemical constituents

Various active ingredients were isolated from the root of *S. baicalensis* by the methods such as high-performance liquid chromatography (HPLC), high-speed counter-current chromatography (HSCCC), thin layer chromatography (TLC), capillary electrophoresis (CE) and microemulsion electrokinetic chromatography (MEKC) [5]. In this paper, a variety of compounds in *S. baicalensis* were summarized, including flavonoids, hydrocarbons, terpenoids, organic acids, aldehydes and ketones, alkaloids, alcohols and steroids. Among them, flavonoids are the main active chemical components of *S. baicalensis.*

2.1 Flavonoids

Scutellaria scutellaria contains 38 kinds of flavonoids for Chrysin (**1**), Pinocembrin (**2**), 7-*O*-Methylchrysin (**3**), Apigenin (**4**), Baicalein (**5**), 5,7,8-Trihydroxyflavone (**6**), (*S*)-7-Hydroxy 5-methoxy-2-pheny1chroman-4-one (**7**), (*S*)-5,7-Dihydroxy-2-(4-hydroxypheny1) chroman-4-one (**8**), 2',5,6,7-Tetrahydroxyflavanone (**9**), Negletein (**10**), Genkwanin (**11**), OroxylinA (**12**), Wogonin (**13**), 4Luteolin (**14**), Isoscutellarein (**15**), Scutellarein (**16**), Sakuranetin (**17**), Eriodictyol (**18**), 2',5,6'7-Tetrahydroxyflavanone (**19**), Isocarthamidin (**20**), 5-hydroxy-7,8-dimethoxyflavone (**21**), 5,7,4'-trihydroxy-8-methoxyflavone (**22**), 5,7,3'-Trihydroxy-6,4',5'-triMethoxyflavone (**23**), Hispidulin (**24**), Viscidulin (**25**), Morin (**26**), 6-hydroxyluteolin (**27**), 5,7,3'-trihydroxy-6,4'5'-trimethoxyflavanone (**28**), Norwogonin-8-*O*-glucuronide (**29**), Scutellarein-7-*O*-glucoside (**30**), Baicalin (**31**), Scutellarm (**32**), Wogonoside (**33**), OroxainA (**34**), APG (**35**), Baicalinmethyleaster (**36**), Isoschaftoside (**37**), and Quercetagetin-7-*O*-glucoside (**38**).

The structures are shown in Fig. 1, and the specific structures are as follows [6-20]:

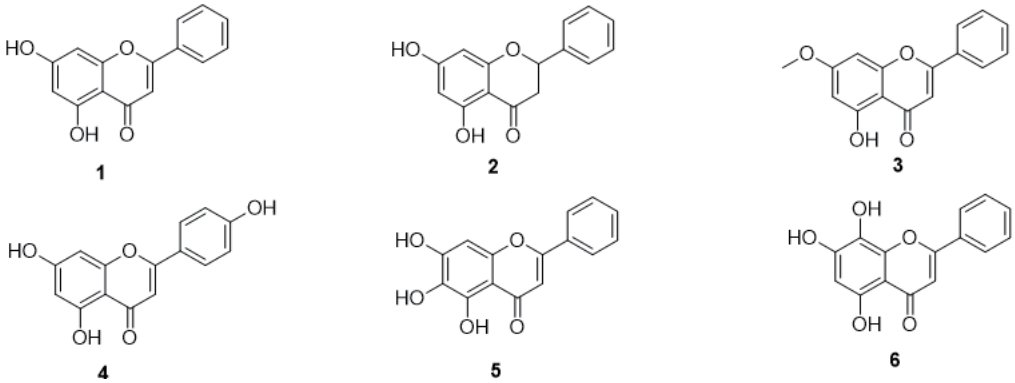
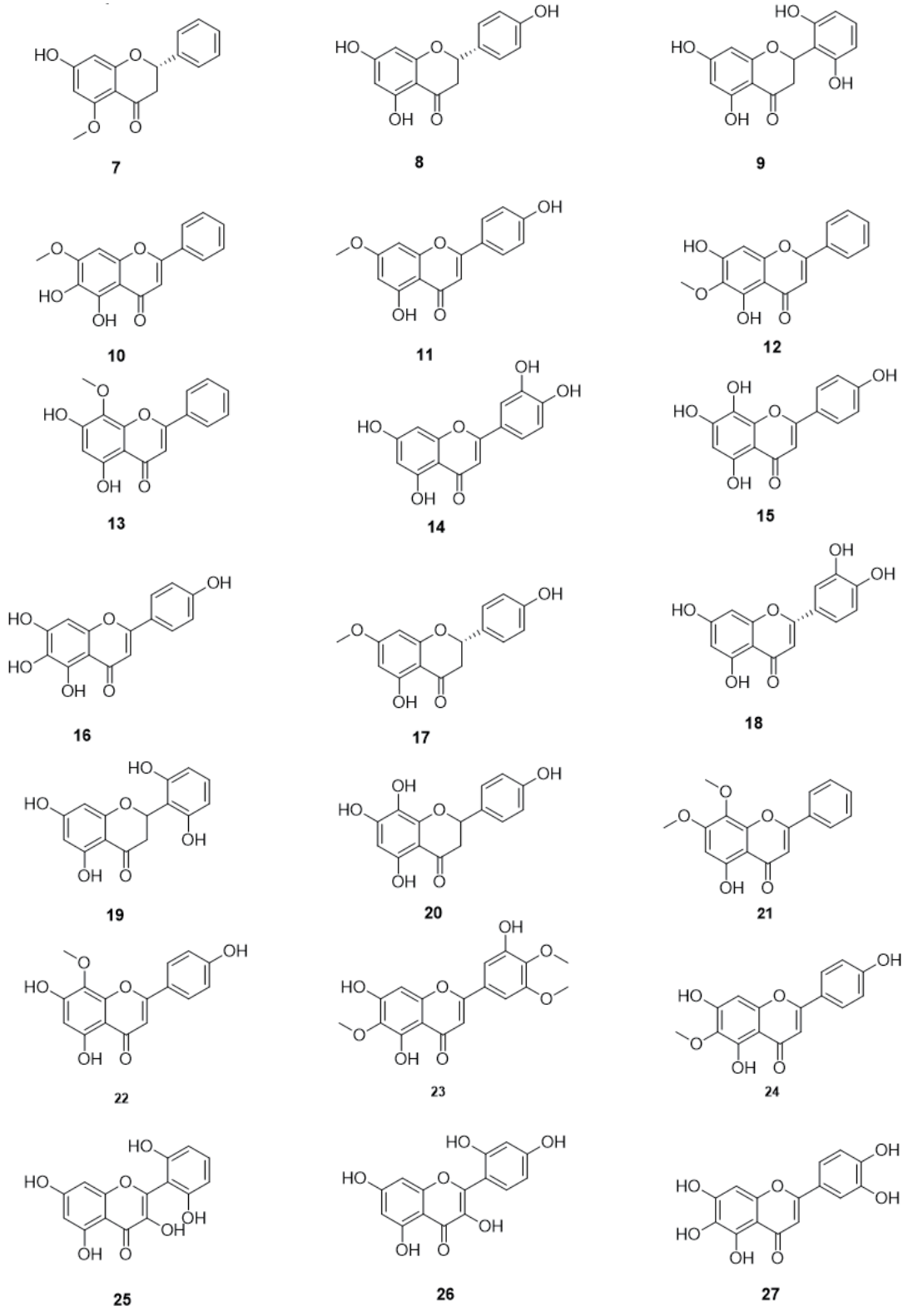
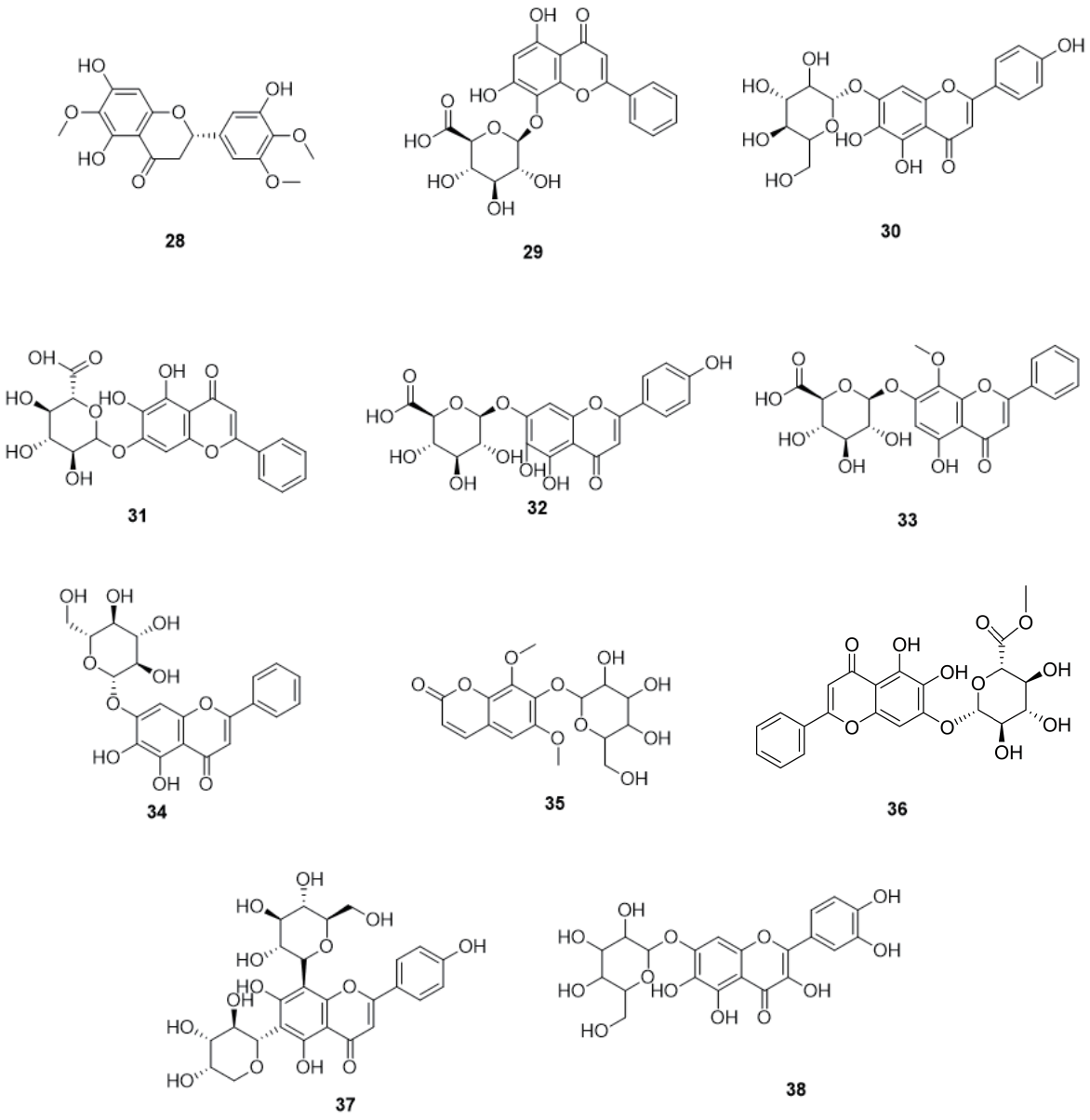


Fig. 1 The structures of flavonoids isolated from *S. baicalensisaa*

(to be continued)



Continued Fig. 1



Continued Fig. 1

2.2 Hydrocarbons

So far, 10 compounds have been isolated from scutellaria baicalensis such as Octane (**39**), Undercane (**40**), 2,3,4-trimethylhexane (**41**), vinylcyclooctane (**42**), isoprene (**43**), Dodecane (**44**), Pentadecane (**45**), 3,7-Dimethy1-Nonane (**46**), 3,7-Dimethyldecane (**47**), and 3,7-Dimethylundecane (**48**). The structures are shown in Fig. 2, and the specific structures are as follows:

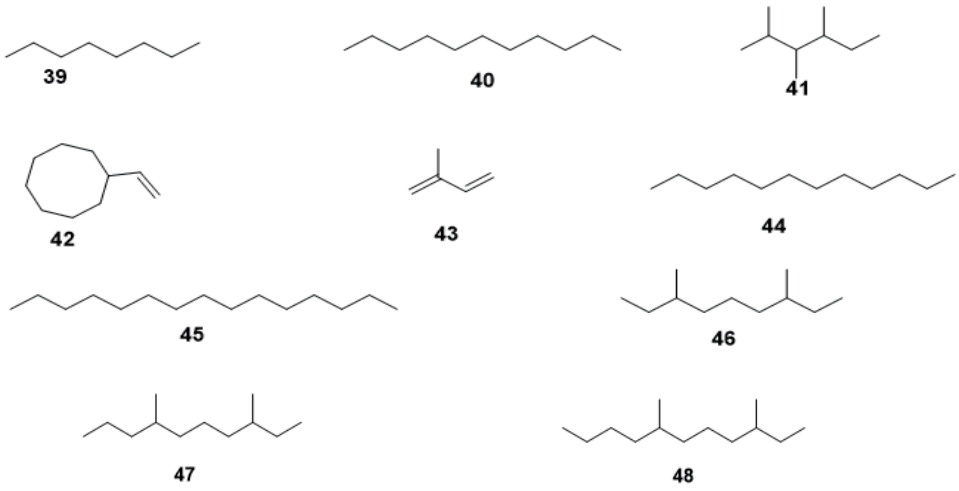


Fig. 2 The structures of hydrocarbons isolated from *S. baicalensis*

2.3 Terpenoids

Scutellaria is also rich in terpenoids, such as Cineole (**49**), Menthone (**50**), *Iso*-Mentone (**51**), Camphor (**52**), Lsobormeol (**53**), Guaiazulene (**54**), *β*-Caryophyllene (**55**), Cedrene (**56**), Germacrene D (**57**), and (2*S*)-3a-Viny1-3-methy1-2*β*-(1-methylviny1)-6*β*-isopropylcyclohexanone (**58**). The specific structures of terpenes is shown in Fig. 3.

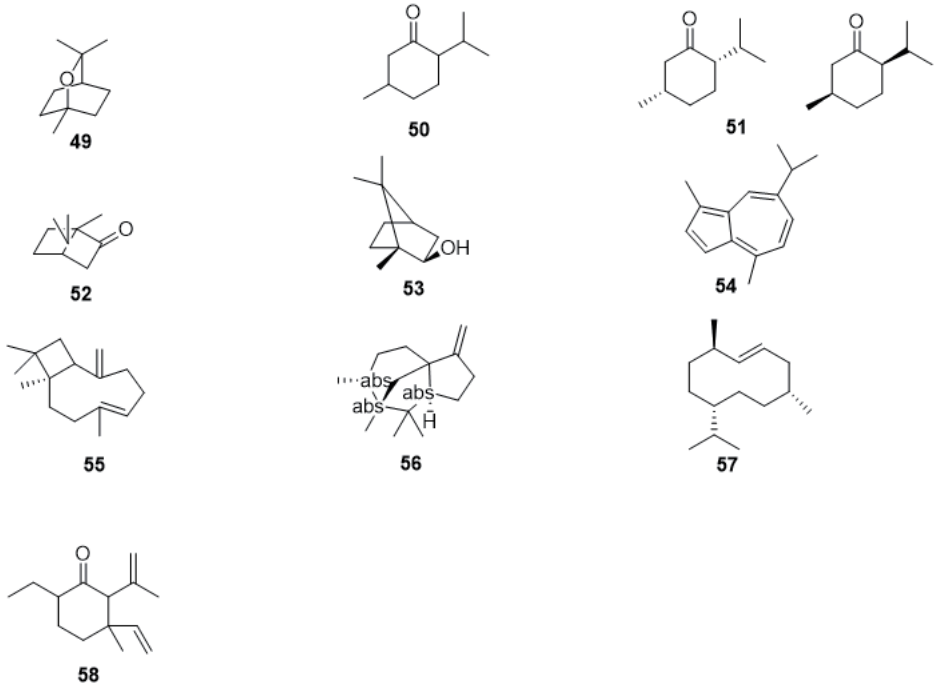


Fig. 3 The structures of terpenoids isolated from *S. baicalensis*

2.4 Organic acids

The proportion of organic acids in scutellaria baicalensis is also large. For example, 2-hydroxypropanoic acid (**59**), Fumaric acid (**60**), hexanoic acid (**61**), butanedioic acid (**62**), Oxalic acid (**63**), Benzoic acid (**64**), Malic acid (**65**), Villic acid (**66**), Citric acid (**67**), Myristic acid (**68**) and Linoleic acid (**69**). The specific structures are shown in Fig. 4.

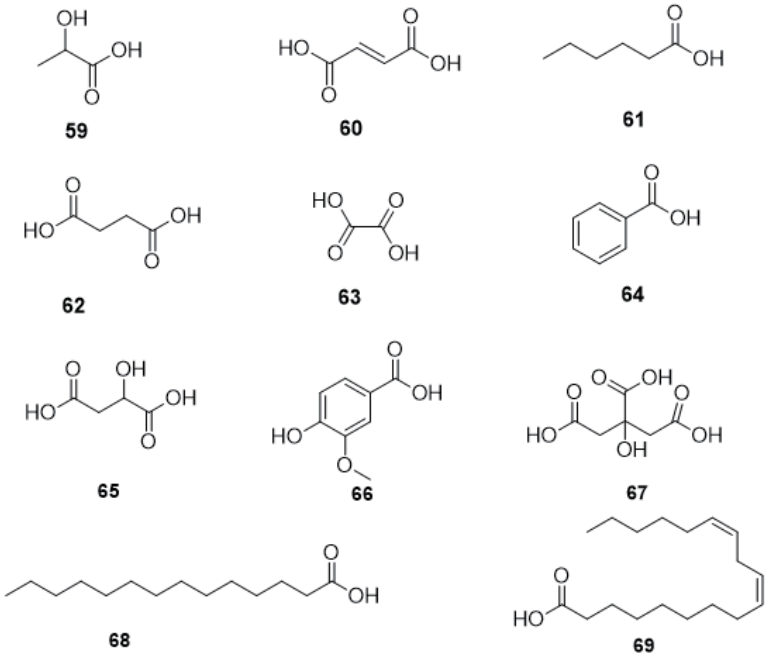


Fig. 4 The structures of Organic acids isolated from *S. baicalensis*

2.5 Aldoketones

At present, 7 aldehydes and ketones have been isolated from *S. baicalensis*, such as Benzene carbonal (**70**), Undecanal (**71**), Syringaldehyde (**72**), Vanillin (**73**), Acetophenone (**74**), and Benzophenone (**75**). Their specific structures are shown in Fig. 5.

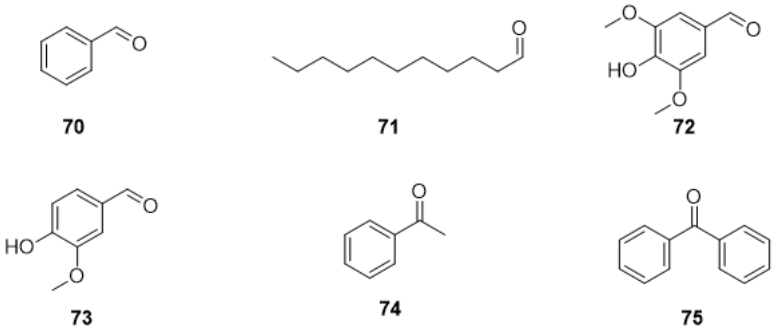


Fig. 5 The structures of aldehydes and ketones isolated from *S. baicalensis*

2.6 Alkaloids

At the same time, *S. baicalensis* also contains a lot of alkaloids, such as pellitorine (**76**), Piperlongumine (**77**), Jatrorrhizin (**78**), Camptothecin (**79**), and 4,11-Diethy1-4,9-dihydroxy-1H-pyrano[3',4':67]indolizino[1,2-b] quinoline-3,14(4H,12H)-dione (**80**). The specific structures are shown in Fig. 6.

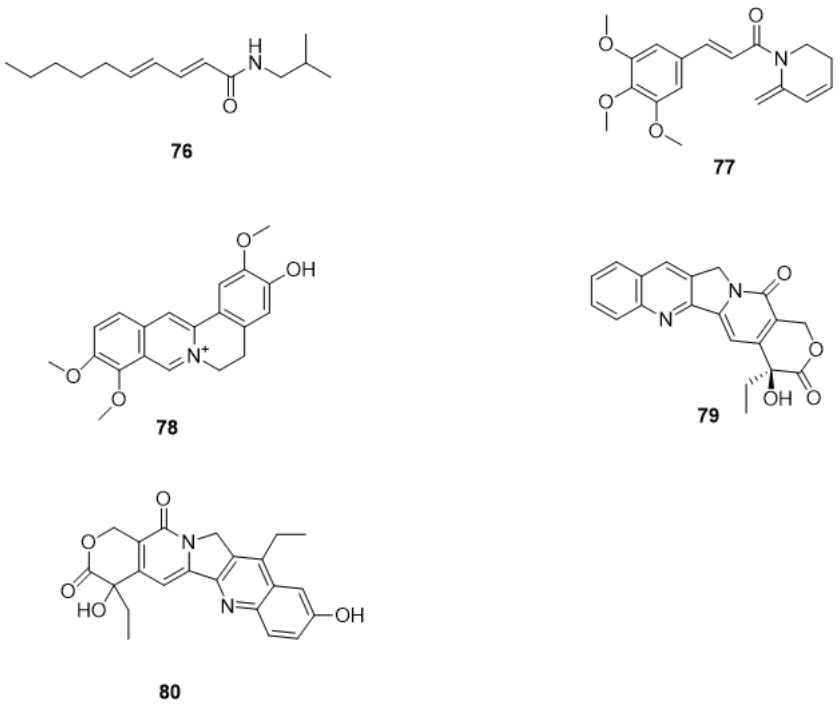


Fig. 6 The structures of alkaloids isolated from *S. baicalensis*

2.7 Alcohols

S. baicalensis contains 5 kinds of alcohols, such as Glycerol (**81**), Adonitol (**82**), Inositol (**83**), 1-Octen-3-ol (**84**), and Linalool (**85**). The specific structures are shown in Fig. 7.

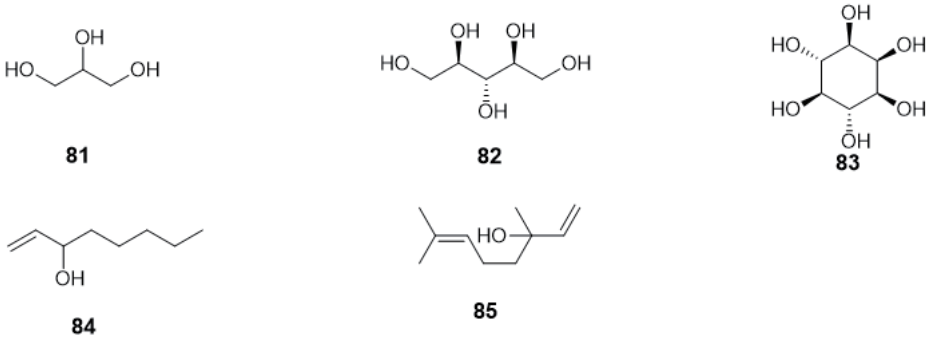


Fig. 7 The structures of alcohols isolated from *S. baicalensis*

2.8 Sterols

S. baicalensis contains 3 kinds of sterols, such as Stigmasterol (**86**), *β*-Sitosterol (**87**), and Daucosterol (**88**). The specific structures are shown in Fig. 8.

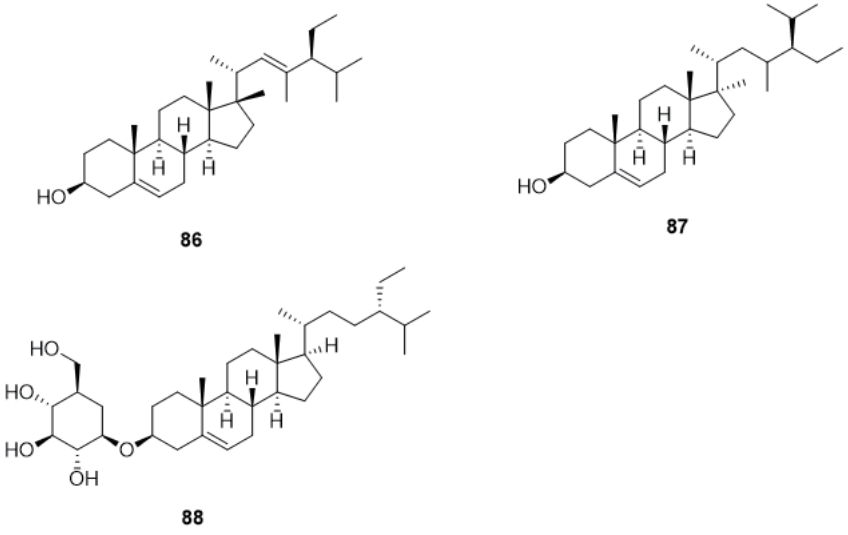


Fig. 8 The structures of sterols isolated from *S. baicalensis*

2.9 Amino acids

S. baicalensis contains many amino acids, such as Threonine (**89**), Alanine (**90**), Isoleucine (**91**), and Tryptophan (**92**). The structures of amino acids are shown in Fig. 9.

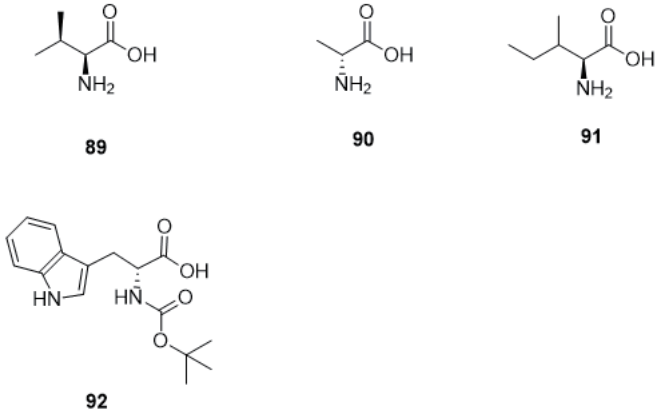


Fig. 9 The structures of amino acids isolated from *S. baicalensis*

3 Pharmacological activity

3.1 Anti-inflammatory activity

Researchers have conducted in-depth research on the anti-inflammatory mechanism of *S. baicalensis* and its components. Results showed that Han baicalin exhibited anti-inflammatory effects by inhibiting the activity of cytokines and baicalin played an anti-inflammatory role by inhibiting tumor necrosis factor-*α* and the expression of interleuin *β* (IL-*β*) [21].

It was found that baicalin in the water extract of *S. baicalensis* reduced A549 cells induced by phobol ester prostaglandin E2 and interleukin-8 (IL-8). The effect was mediated through the inhibition of extracellular regulated protein kinases, stress-activated protein kinases and p38 phosphorylation, thereby suppressing the signal transduction of mitogen-activated protein kinase. Another study showed that baicalein inhibited NOD-like receptor thermal protein domain associated protein 3, NLRP3)/caspase-1/aporin D pathway to reverse 1-methyl-4-phenyl-1,2,3,6-tetrahydropyridine induced neuritis in mice illness [22,23].

Studies have found that baicalein in scutellaria significantly reduced the production of nitric oxide (NO) in BV2 cells induced by lipopolysaccharides (LPS), thus playing an anti-inflammatory role. Zhang et al. isolated 6-C-(B-arabinofuranosyl)-8-C-(B-d-glucopyranosyl) chrysin and 6-C-(B-d-glucopyranosyl)-8-C-(6-C-(B-D-Glucopyranosyl)) chrysin from *S. baicalensis*. After that, griess reagent and enzyme-linked immunosorbent assay were used to detect the effects of this compound on NO, TNF-α, IL-6, PGE and cycloxygenase in LPS-induced macrophages. The results showed that the expression levels of NO, TNF-α, IL-6, PGE and COX2 in macrophages were significantly decreased, and the survival rate of macrophages was significantly improved, indicating that *S. baicalicalum* had a certain anti-inflammatory effect [24,25].

Baicalein helps to reduce the development of antibiotic resistance and inhibits the NorA efflux pump of bacteria. This mechanism helps to increase the concentration of antibiotics in the bacteria, thereby enhancing its antibacterial effect. *S. baicalensis* has been shown to inhibit drug-resistant bacteria in laboratory studies, and its combination with antibiotics may help reduce the development of drug resistance, while Coptis has no such effect [26].

3.2 Antibacterial activity

Studies have found that baicalin can damage the cell membrane of Escherichia coli, increase the permeability of the cell membrane, and make the substances in the bacteria outside infiltration, bacterial DNA escape, thus playing an antibacterial role [27]. Both Staphylococcus and Escherichia coli have antibacterial activity, and baicalin has antibacterial activity. Staphylococcus aureus has slightly higher anti-fungal activity than Escherichia intestinalis, while the inhibitory ability of baicalein on Escherichia intestinalis was slightly better than that on golden yellow staphylococcus chromosus [28]. In summary, baicalin has strong antibacterial properties and can be widely used as an effective ingredient in antibiotics.

3.3 Anti-tumor mechanism

The flavonoids in *S. baicalensis* have extensive antitumor activity. Pharmacological studies have shown that flavonoids in *S. baicalensis* have anti-tumor effects by regulating the cycoperoxidase pathway and lipid oxidase pathway related to the arachidonic acid system. Meng Lu et al. found that baicalin changed the protein expression of apoptosis-related genes, thus inducing the apoptosis of human hepatoma HepG-2 cells. The anti-tumor effect of baicalein is characterized by multiple pathways, targets and links, which can not only block the cell cycle, interfere with the proliferation of tumor cells, promote the apoptosis of tumor cells, but also enhance the immune function of immune cells [29-31].

3.4 Antioxidation

S. baicalensis has antioxidant activity, which can remove the free groups that harm the

body and reduce the damage of oxidative stress to the body. Researchers found that baicalein, baicalin and visidurin III showed high activity in the determination of free radical scavenging activity [32]. The harm of metal ions to human health involves multiple biological processes, impairing health through oxidative stress and direct interference with cell function [33]. Studies have shown that many metals that are harmful to the human body are not easily excreted from the body and are easily distributed and accumulated in the body [34]. It has been reported that baicalin exerts its antioxidant capacity by scavenging free radicals, activating antioxidants, forming metal ion compounds, and eliminating reactive oxygen species and active nitrogen [35]. Shi Yajun et al. used *in vitro* dibenzoyl trapped radical (DPPH) model to determine the antioxidant capacity of *S. baicalensis* extract, and found that the antioxidant capacity of the extract increased with the increase of baicalin content in the extract [36].

3.5 Liver-protective effect

Li et al. found that *S. baicalensis* reduced fructose-induced lipid accumulation in the liver of rats [37]. *S. baicalensis* and its active ingredients have anti-hepatic fibrosis *in vivo* and *in vitro*. *In vivo*, scutellaria played an anti-fibrosis role by resisting oxidation and activating peroxisome proliferator receptors [38-40].

3.6 Neuroprotective effect

It was found that baicalein alleviated motor dysfunction and dopaminergic neuronal degeneration in MPTP-induced Parkinson's disease model mice [41].

4 Conclusion

There are many chemical components in *S. baicalensis*, including flavonoids, hydrocarbons, terpenoids, organic acids, aldehydes and ketones, alkaloids, alcohols and steroids, among which flavonoids are the main active components. As a traditional Chinese medicinal material, *S. baicalensis* has been widely studied and applied in recent years. *S. baicalensis* has a wide range of pharmacological effects, such as anti-inflammatory, antibacterial, anti-tumor, liver and neuron protection, and it has high medicinal value in clinical practice. With the development of modern medical science and technology and the deepening of research, *S. baicalensis* will have a broader application prospect.

Acknowledgements

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