Review

Chemical composition and biological activities of *Panax notoginseng*

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Abstract

Panax notoginseng* (*P. notoginseng*), a valuable traditional Chinese medicine, is the dried root of plants in *Acanthopanax gracilistylus* family, with the effect of dispersing blood stasis, eliminating swelling and relieving pain. With the development of modern medicine, the active ingredients and mechanisms of *P. notoginseng* have been gradually revealed. The present paper systematically reviews the chemical composition and biological activities of *P. nologinseng*, to provide a scientific basis and reference for detailed research on *P. nologinseng.

Keywords: *Panax notoginseng*; chemical composition; biological activity

1 Introduction

Panax notoginseng (*P. notoginseng*), the dried root of ginseng of *Acanthaceae*, is a traditional and precious Chinese medicinal herb with important medicinal value and wide clinical application. It is mainly distributed in Wenshan and Jingxi of Yunnan Province [1]. Traditional Chinese medicine believes that *P. notoginseng* has the effect of stopping bleeding and removing blood stasis, promoting blood circulation and fixing pain [2]. It is widely used in the clinical prevention and treatment of cardiovascular and cerebrovascular diseases and various hemorrhagic diseases. The main compounds isolated from *P. notoginseng* are saponins, flavonoids, volatile oils, organic acids, and polysaccharides [3]. Modern medical research shows that *P. notoginseng* functions in the blood system, digestive system, liver and immune system [4]. The chemical composition and biological activity of *P. notoginseng* were reviewed in this paper to lay a foundation for the clinical application of *P. notoginseng*.

2 Chemical composition

P. notoginseng contains a variety of compounds, including saponins, flavonoids, volatile oils, organic acids, polysaccharides and other chemical components.

These authors have no conflict of interest to declare.

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2.1 Saponins

Saponins are the main chemical and effective components of *P. notoginseng*. More than 70 monomeric saponins have been isolated from different parts of *P. notoginseng*. Among them, Yang found five main saponins (**1-5**) [4]. In addition, another 22 main saponins (**6-27**) were found in *P. notoginseng* later [5]. In addition, there are 44 rare saponins (**28-71**) [6]. Table 1 and Fig. 1 show the molecular formula and structural formula of these saponins.

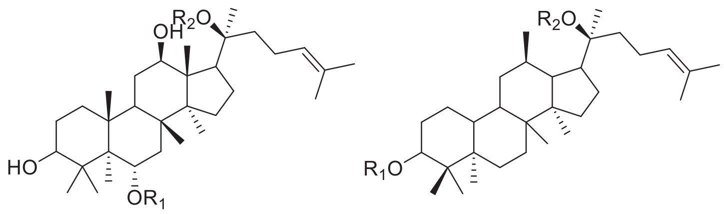

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Fig. 1 Structural formulas of saponins from *P. notoginseng*

Table 1 Molecular formulas of saponins

No.	Name	R_1	R_2	References
1	*P. notoginseng* R_1	glc(*β*1→6)glc	glc	[4]
2	ginsenoside Rg_1	glc	glc	[4]
3	ginsenoside Re	glc(*β*1→6)rha	glc	[4]
4	ginsenoside Rd	glc(*β*1→2)glc	glc	[4]
5	ginsenoside Rb_1	glc(*β*1→2)glc	glc(*β*1→6)glc	[4]
6	ginsenoside Rc	glc(*β*1→2)glc	glc(*β*1→6)ara(f)	[5]
7	ginsenoside Rb_3	glc(*β*1→2)glc	glc(*β*1→6)xyl	[5]
8	ginsenoside Rb_2	glc(*β*1→2)glc	glc(*β*1→6)ara(p)	[5]
9	ginsenoside Ck	H	glc	[5]
10	ginsenoside Mc	H	glc(*β*1→6)rha	[5]
11	ginsenoside F_2	glc	glc	[5]
12	ginsenoside CMx	glc(*β*1→6)glc	rha(*β*1→6)glc	[5]
13	ginsenoside Rh_2	glc	H	[5]
14	notoginsenoside SY_1	glc	glc(*β*1→6)glc	[5]
15	notoginsenoside Fh_6	glc	glc(*β*1→6)rha	[5]
16	notoginsenoside ng_4	glc	rha(*β*1→6)glc	[5]
17	notoginsenoside Lk_2	H	glc(*β*1→6)glc	[5]
18	notoginsenoside Fe	glc	glc(*β*1→6)ara(f)	[5]

(to be continued)

Continued Table 1

No.	Name	R_1	R_2	References
19	notoginsenoside Fa	glc(β1→2)glc(β1→2)glc	glc(β1→6)glc	[5]
20	notoginsenoside Fc	glc(β1→2)glc(β1→2)xyl	glc(β1→6)xyl	[5]
21	notoginsenoside Fz	glc(β1→2)glc(β1→2)glc	glc(β1→6)ara	[5]
22	notoginsenoside Fh_1	glc(β1→2)glc(β1→2)glc	glc(β1→6)glc	[5]
23	notoginsenoside S	glc(β1→2)glc(β1→2)glc	glc(β1→2)rha(β1→2)glc	[5]
24	notoginsenoside D	glc(β1→2)glc(β1→2)glc	glc(β1→6)glc(β1→2)glc	[5]
25	notoginsenoside Q	glc	glc(β1→6)glc	[5]
26	notoginsenoside Ra_0	glc(β1→2)glc(β1→2)glc	glc(β1→6)glc	[5]
27	notoginsenoside FP_2	glc(β1→2)glc(β1→2)glc	glc(β1→6)fru	[5]
28	notoginsenoside Fh_5	H	glc(β1→6)fru	[6]
29	notoginsenoside nL B_1	glc	glc(β1→6)ara(f)	[6]
30	notoginsenoside nL B_2	glc	glc(β1→6)ara(p)	[6]
31	notoginsenoside nL B_3	glc	glc(β1→6)glc	[6]
32	notoginsenoside nL A_1	glc(β1→2)glc(β1→2)xyl	glc(β1→6)xyl	[6]
33	notoginsenoside nL A_2	glc(β1→2)glc(β1→2)xyl	glc(β1→6)ara(p)	[6]
34	notoginsenoside nL A_3	glc(β1→2)glc(β1→2)glc	glc(β1→6) ara(f)	[6]
35	notoginsenoside nL A_4	glc(β1→2)glc(β1→2)glc	glc(β1→6)glc(R)	[6]
36	notoginsenoside Fh_3	glc(β1→5)fru	glc	[6]
37	notoginsenoside Fh_4	glc(β1→5)glc	glc	[6]
38	notoginsenoside nL g_1	glc	glc(β1→6)glc	[6]
39	notoginsenoside nL g_2	glc(β1→2)glc(β1→2)glc	glc(β1→5)glc	[6]
40	notoginsenoside nL H_1	glc	glc(β1→6)fru	[6]
41	notoginsenoside nL H_2	glc	glc(β1→6)glc(S)	[6]
42	notoginsenoside Fh_2	glc(β1→2)glc(β1→2)glc	glc(β1→6)glc	[6]
43	notoginsenoside ng_2	glc(β1→2)glc	glc(β1→5)fru	[6]
44	notoginsenoside nL C_1	glc	glc(β1→6)xyl(R)	[6]
45	notoginsenoside nL C_2	glc	glc(β1→6)xyl(S)	[6]
46	notoginsenoside nL C_3	glc(β1→2)glc	glc(β1→6)glc(R)	[6]
47	notoginsenoside Lk_4	glc	glc(β1→5)xyl(S)	[6]
48	notoginsenoside nL E_1	glc	glc(β1→5)xyl(R)	[6]
49	notoginsenoside nL E_3	glc(β1→2)glc(β1→2)glc	glc(β1→5)xyl	[6]

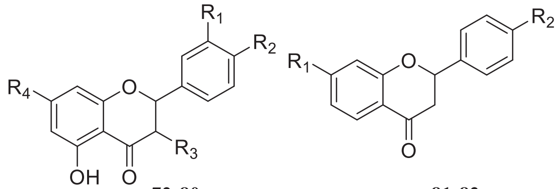
(to be continued)

Continued Table 1

No.	Name	R_1	R_2	References
50	notoginsenoside nL E_4	glc(β1→2)glc(β1→2)glc	glc(β1→6)glc	[6]
51	notoginsenoside nL F_1	glc(β1→2)glc	glc(β1→6)glc(S)	[6]
52	notoginsenoside nL E_2	glc(β1→2)glc	glc(β1→5)xyl	[6]
53	notoginsenoside ng_1	glc	glc(β1→6)glc(S)	[6]
54	quinquefoloside Lb	glc(β1→2)glc	glc(β1→6)glc	[6]
55	notoginsenoside nL H_1	glc	glc(β1→5)ara(f)	[6]
56	notoginsenoside nL H_2	glc	glc(β1→6)xyl	[6]
57	notoginsenoside nL H_3	glc(β1→2)glc(β1→2)glc	glc(β1→6)glc	[6]
58	notoginsenoside nL I	glc	glc(β1→6)glc(S)	[6]
59	notoginsenoside nL J	glc(β1→2)glc(β1→2)xyl	glc(β1→6)glc	[6]
60	notoginsenoside ng_3	glc(β1→2)glc	glc(β1→6)glc	[6]
61	notoginsenoside LX	glc	glc(β1→5)xyl(S)	[6]
62	notoginsenoside LY	H	glc(β1→5)xyl	[6]
63	Panaxdiol	H	H	[6]
64	notoginsenoside SY_2	glc(β1→2)glc(β1→2)xyl	H	[6]
65	gypenoside A	glc(β1→2)glc(β1→2)xyl	glc(β1→6)ara(f)	[6]
66	gypenoside B	glc(β1→2)glc(β1→2)xyl	glc(β1→6)glc	[6]
67	gypenoside C	glc(β1→2)glc(β1→2)xyl	glc(β1→6)glc	[6]
68	ginsenosideII	glc(β1→2)glc	glc	[6]
69	gypenoside XXII	glc	glc(β1→6)ara(f)	[6]
70	gypenoside XVII	glc	glc(β1→6)glc	[6]
71	gypenoside XIII	glc	glc(β1→6)ara(p)	[6]

2.2 Flavonoids

Flavonoids exist widely in nature. At present, eleven flavonoids have been found in *P. notoginseng* [7], as shown in Table 2 and Fig. 2.



72-80 **81-82**

Fig. 2 Structural formulas of flavonoids from *P. notoginseng*

Table 2 Molecular formulas of flavonoids

No.	Name	R_1	R_2	R_3	R_4	References
72	Quercetin	OH	OH	OH	OH	[7]
73	quercetin 3-o-sophoroside	OH	OH	-O-glc(*β*1→2)glc	OH	[7]
74	kaempferol-3-O-alpha-L-rhamnoside	H	OH	-O-rha	OH	[7]
75	kaempferol-3-o -(2 “,3 “-di-trans p-hydroxycinnamyl) -*α*-L-rhamnoside	H	OH	-O-rha	OH	[7]
76	kaempferol	H	OH	OH	OH	[7]
77	kaempferol-7-O-alpha-L-rhamnoside	H	OH	OH	-O-rha	[6]
78	kaempferol-3-O-*β*-D-galactoside	H	OH	-O-gal	OH	[7]
79	kaempferol-3-o-*β*-D-galactose (2-1) glucoside	H	OH	-O-gal(*β*1→2)glc	OH	[7]
80	quercetin 3-O-*β*-D-galactose (2-1) glucoside	OH	OH	-O-glc(*β*1→2)glc	OH	[7]
81	Liquiritin	OH	OH	---	---	[7]
82	Glycyrrhizin	OH	-O-gal(*β*1→2)glc	---	---	[7]

2.3 Polysaccharide

The structural molecules of polysaccharides in *P. notoginseng* are complex and diverse, composed of different kinds of monosaccharides. Although sharing the same composition, polysaccharides are different in the main and side chains of monosaccharides, and the structures that make up polysaccharides are also different, and the main monosaccharide components of these polysaccharides include aldehydo-*L*-arabinose (**83**), *D*-Glucose (**84**), *D*-Xylose (**85**), Demannose (**86**), *L*-Rhamnose (**87**), as shown in Fig. 3 [8].

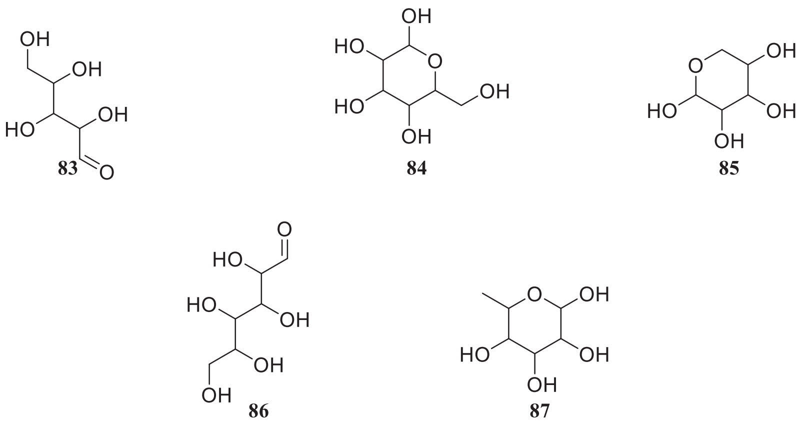
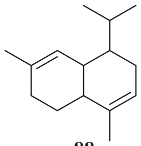


Fig. 3 Structural formulas of monosaccharides from *P. notoginseng*

2.4 Volatile oils

The volatile oil of *P. notoginseng* has complex composition. Lu et al [9]. isolated a variety of volatile components using the methods of ether cold immersion and gradient extraction, such as *γ*-Muurolene (**88**), Cyperene (**89**), *α*-Elemene (**90**), Cadinene (**91**), *α*-Gurjunene (**92**), *α*-Guaiene (**93**), 2,6-Ditert-buty-4-methyl phenol (**94**), 2,8-Dimethyl-5-acteyl-bicyclo[5,3,0]decaiene-1,8 (**95**), Palmitic acid methylate (**96**), Palmitic acid aceticate (**97**), Diene-stearic acid methylate (**98**), Diene-stearic acid aceticate (**99**), Benzene-bis (**100**), Acetic acid (**101**), Heplanoic acid (**102**), Octanoic acid (**103**), Nonanoic acid (**104**), Palmitic acid (**105**), Isoally-benzene (**106**), Phenyl-ethanal (**107**), *α*-Dimethyl-benzenemethanol (**108**), 1-Methoxthyl-benzene (**109**), 1-2-One-nonene-3 (**110**), 2,2,2-Ttriethoxyl-ethanol (**111**), 1-Methyl-4-isoallyl-cyclohexane (**112**), Tetradecane (**113**), Octadecane (**114**), Nonadecane (**115**), Docosane (**116**), and Tricosane (**117**), as shown in Fig. 4.



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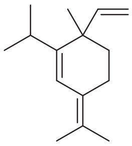

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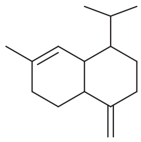

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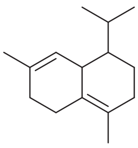

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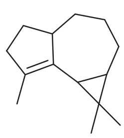

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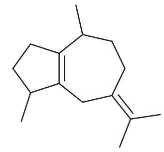

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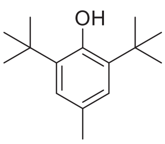

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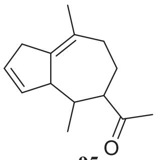

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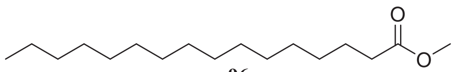

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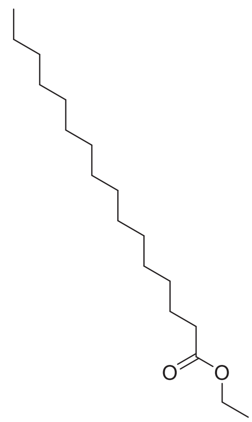

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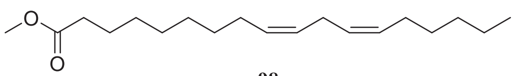

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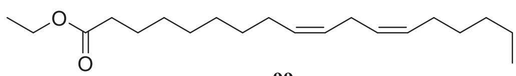

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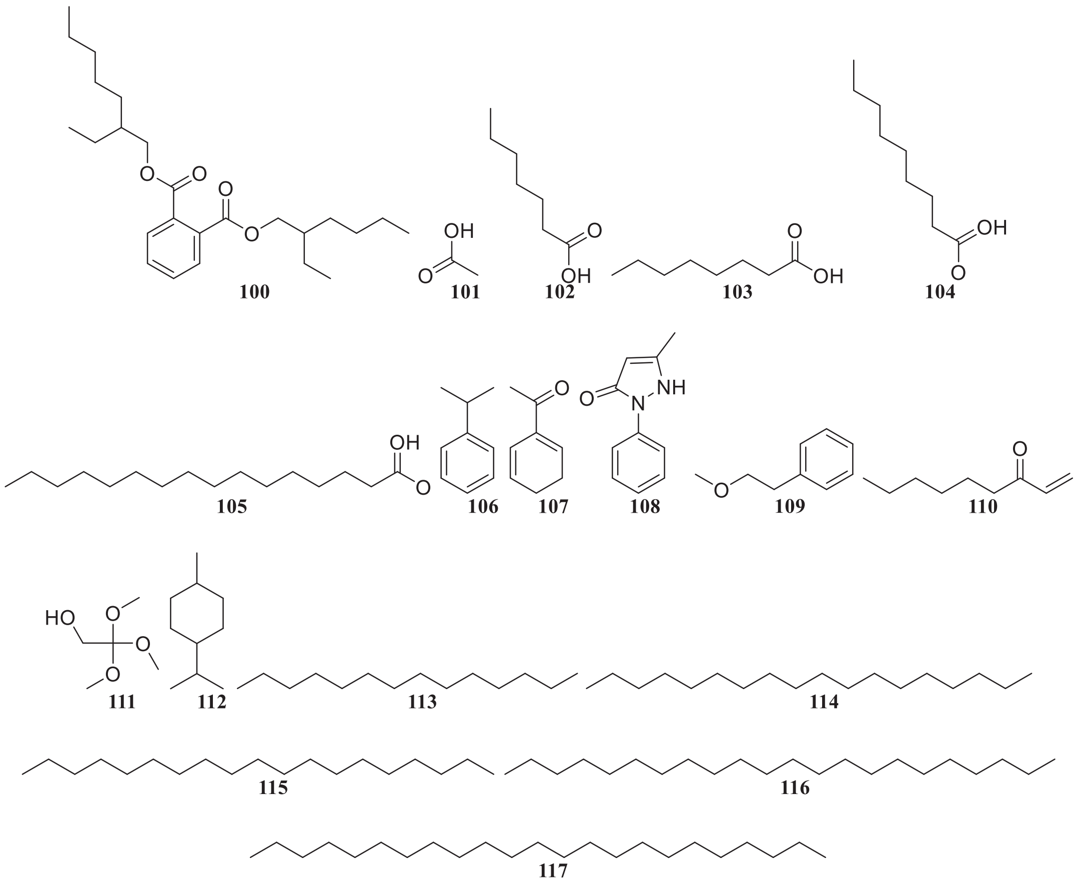

Fig. 4 Structural formulas of volatile oils from *P. notoginseng*

2.5 Other ingredients

Dentichine is one of the active ingredients of *P. notoginseng*. It is a special amino acid with the structure of *β*-n-oxalo-L-*α*,*β*-diaminopropionic acid (**118**), and it can be artificially synthesized, as shown in Fig. 5 [10].

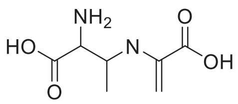

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Fig. 5 Structural formula of dentichine from *P. notoginseng*

P. notoginseng also contains trace elements, the profiles of which are influenced by its growing environment. Contents of various trace elements in *P. notoginseng* prove the impact of geographical origins and geological backgrounds. As research progresses, more components will be identified from *P. notoginseng* in the future.

3 Pharmacological effects

Modern research shows that *P. notoginseng* has various pharmacological effects, exerted on the blood system, digestive system, liver and immune system.

3.1 Effects on the blood system

3.1.1 Hemostatic effect

Denciemne, a water-soluble component of *P. notoginseng*, can shorten the coagulation time of mice and significantly increase the number of platelets. Zhang et al. applied normal saline, 1.25%, 2.5% and 5% denciemne respectively to the abdominal cavity of mice at a dose of 10 mg/kg, and measured the effect of three different concentrations of denciemne on the coagulation time and maximum platelet aggregation rate of mice by slide method and compared the results with the blank group [11]. The experimental results showed that the mice injected with denciemne had a faster blood coagulation rate than the blank control group, and the blood coagulation rate of the high-concentration control group was faster than that of the low-concentration control group. These results indicate that *P. notoginseng* has a good hemostatic effect .

3.1.2 Blood-invigorating effect

P. notoginseng can both promote blood clotting and dissolve various blood clots. It has the effects of promoting blood circulation and removing blood stasis. The blood-activating ingredient in *P. notoginseng* has been proved to be ginseng with triol saponins represented by Rg1, while diol saponins have no such effect. Wang et al. gave 70% *P. notoginseng* methanol extract to mice at doses of 50, 100, 200 mg/kg orally, and the results showed that, compared with other groups, the number of platelets in the 200 mg/kg group was significantly reduced, the reduction of fibrin was significantly inhibited, and the globulin dissolution time (ELT) was significantly shortened [12]. Li et al. also concluded that the action links of ginsenoside Rg1 in *P. notoginseng* include inhibiting platelet adhesion and aggregation, antithrombin, promoting fibrinolysis and other processes [13]. These processes promote blood flow, thus proving the blood-activating effect of *P. notoginseng*.

3.1.3 Blood-replenishing effect

In recent years, experimental and clinical studies have also found that *P. notoginseng* also has blood-replenishing effect and can increase the number of peripheral red cells and white blood cells. Wang et al. studied the effect of *P. notoginseng* total saponins (PnS) on the proliferation and mechanism of mouse granuleous monoline hematopoietic progenitor cells by using experimental hematology techniques such as *in vitro* culture of hematopoietic cells and detection of biological activity of hematopoietic growth factors [14]. The results showed that PnS had a proliferative effect on granulocyte-monocyte and erythroid progenitor cells in normal or anemic mice. The splenocyte and fibroblast culture supernatant prepared by PnS induction has a high stimulating activity on the proliferation of erythroid progenitor cells, suggesting that it induces fibroblasts and lymphocytes in the hematopoietic microenvironment to secrete highly active hematopoietic regulatory factors or co-hematopoietic growth factors. Jiang et al. also found that *P. notoginseng* can replenish blood by promoting the proliferation of hematopoietic stem cells, improving the microenvironment of hematopoietic stem cells, protecting hematopoietic organs, regulating the body's immunity, and regulating the metabolism and related proteins [15].

3.2 Effect on the digestive system

Shi et al. explored the mechanism of *P. notoginseng* in the treatment of precancerous lesions of gastric cancer at the cellular and molecular level, and transformed human gastric mucosal epithelial cell line gES-1 with methylnitronitroguanidine

(Mnng) [16]. The proapoptotic effect of PnS on transformed cells was detected by electron microscopy, live cell fluorescence staining and terminal deoxyribonucleotide transfer enzyme labeling (TUnEL method), and retinoic acid (RA) was used as the control. The results showed that treatment with 200 mg/L PnS for 48 h significantly promoted the apoptosis of transformed cells, while 0.00001 mol/L RA had no significant effect on the apoptosis ratio of transformed cells, indicating that *P. notoginseng* can promote the apoptosis of human gastric mucosal epithelial cells transformed by Mnng, which may be one of the mechanisms of *P. notoginseng* in the treatment of gastric precancerous lesions.

3.3 Effect on the liver

3.3.1 Effect on liver metabolism

Peng et al. observed the effect of PnS on rat models of liver injury induced by perfusion *in vitro*, and the results showed that PnS could significantly increase vascular flow and improve liver microcirculation [17]. Hemorheological observation was performed on 13 patients with chronic hepatitis before and after treatment with *P. ginseng* injection. After three months of treatment, the whole blood viscosity, ESR, k value of ESR equation, erythrocyte electrophoresis rate and fibrinogen content of the patients were significantly reduced. They believed that *P. ginseng* could relieve blood thickness, viscosity, aggregation and coagulation, and improve liver circulation and increases blood flow.

3.3.2 Inhibition of liver tumor cells.

Wang found that *P. notoginseng* polysaccharide could reduce the levels of ALT (alanine transaminase) and AST (aspartate aminotransferase) in serum after liver ischemia-reperfusion injury in rats, alleviate the pathological changes of liver tissue in rats, and protect HIRI in rats [18].

The effect of *P. notoginseng* polysaccharide on HIRI (hepatic ischemia reperfusion injury) in rats may be related to the up-regulation of HO-1 (heme oxygenase 1) and down-regulation of TLR4 (toll-like receptor 4) expression in liver tissue, and the alleviation of inflammation and oxidative stress.

3.3.3 Hepatoprotective effect

Total saponins of *P. notoginseng* can increase the content of superoxide dismutase in liver tissue and serum, reduce the consumption of liver glycogen, improve liver microcirculation, alleviate the damage of mitochondria, endoplasmic reticulum and other organelles and liver fibrosis. Wei et al. randomly divided 60 mice into five groups, respectively administered drugs, and conducted controlled trials [19]. The experimental results showed that *P. notoginseng* saponins, *P. notoginseng* flavones and *P. notoginseng* polysaccharide could significantly reduce the liver, spleen and thymus indexes of mice. After administration of *P. notoginseng* saponins, *P. notoginseng* flavones and *P. notoginseng* polysaccharide, the liver histological observation showed swelling and necrosis of liver cells, and the infiltration of a large number of inflammatory cells in and around the portal area was significantly reduced. These results indicated that total saponins, flavonoids and polysaccharides of *P. notoginseng* could protect mice from immune liver injury.

3.4 Effects on the immune system

Li et al. found through research that dencichine in *P. notoginseng* could resist inflammation by inhibiting pathogenic factors that caused inflammation and was non-toxic to cells [20]. Li et al. found through experiments that the total saponins of *P. notoginseng* had immunomodulatory effects, and the saponins after fermentation had stronger immunomodulatory effects, proving that *P. notoginseng* has immunomodulatory effects [21].

4 Summary

This paper reviews the chemical constituents and pharmacological activities of *P. notoginseng*. It has many pharmacological effects, such as promoting blood circulation, reducing swelling and pain, immune regulation, neuroprotection and anti-oxidation. Its chemical constituents include saponins, flavonoids, polysaccharides, volatile oils and amino acids, and saponins are the main active substances. *P. notoginseng* R1, ginsenoside Rg1, ginsenoside Rb1, ginsenoside Rd and ginsenoside Re are the five most representative saponins in *P. notoginseng*. It plays an important role in promoting blood circulation, achieving hemostasis, and replenishing blood. Since the chemical composition differs between different parts of *P. notoginseng*, researchers can target these differences to unlock new medicinal values and clinical applications of *P. notoginseng*. This article not only systematically expounds the physicochemical properties and biological activities of *P. notoginseng*, but also provides a scientific basis for its application in fields such as drug development, food industry and precision medicine. The multi-target and low-toxicity characteristics of *P. notoginseng* endows it with broad prospects in the prevention and treatment of chronic diseases and the health industry. However, to fully realize its potential, future efforts must strengthen clinical research and achieve breakthroughs in industrialization technologies. Through interdisciplinary cooperation and technological innovation, future research on *P. notoginseng* will deepen. This will include identifying more effective ingredients, exploring the mechanism of action, optimizing the preparation process, and improving quality standards. Ultimately, these advances will expand its applications into broader fields, contributing significantly to human health [22].

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