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Review Article

Phytochemistry and Biological Activities of *Poria*

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Poria is a common Traditional Chinese Medicine in clinic. In recent years, the chemical and pharmacological studies of *Poria* have made great progress, triterpenes and polysaccharides have been isolated, and various types of compounds containing lipids, octanoic acids, fatty acids, and trace elements have been found. In this paper, we reviewed the literature, summarized the main compound types, and reviewed in detail their pharmacological effects in antitumor, immunomodulatory, effects on kidney, hepatoprotective activity, effects on blood sugar, antioxidant effects, anti-inflammatory effects, effects on the gut, antidepressant, and so on, and also categorized the compounds with the same or similar pharmacological effects to provide a reference for the in-depth study of the material basis of the pharmacological effect, quality standards, and pharmacological activity of *Poria*.

1. Introduction

Poria is the dry sclerotia of Basidiomycota, Agaricomycetes, Polyporaceae, and fungus *Poria cocos* (Schw.) Wolf. It is cultivated in many regions of China, mainly in Anhui, Yunnan, and Hubei Province [1, 2]. *Poria* has a long history, which was the first recorded in Shennong Materia Medica [3, 4]. During the Qin and Han Dynasties, people often used *Poria* as a tea drink with the belief that it could prolong life [5, 6].

So far, the triterpenes, polysaccharides, sterols, fatty acids, and volatile oil are the main chemical components found in *Poria*, and the triterpenes and polysaccharides are the most active compounds, according to previous pharmacological studies. Moreover, pharmacological research showed that *Poria* had antitumor, antioxidation, anti-inflammation, diuresis, immune regulation, and intestinal regulation [2, 7]. It is also used to treat uterine fibroids, chronic pelvic inflammatory disease, endometriosis, ovarian cyst, early pregnancy abortion, menstrual abdominal pain, medical abortion, cold, headache, colitis, arthritis, urinary tract infection, nephritis, and some tumor diseases, such as esophageal cancer and ovarian cancer [7, 8]. Therefore, this paper summarized the chemical composition and pharmacological activity of *Poria* based on comprehensive literature analysis, hoping to provide a reference for the in-depth research of scientific researchers and the clinical application of medical workers.

2. Chemical Composition Study

The chemical composition of *Poria* was collected from relevant literature through Web of Science, Wanfang.com, CNKI.com, BaiduAcademic.com, and Duxiu.com. Compounds obtained from *Poria* during the period from 1939 to 2020 were collected and classified according to the structural type. It is evidenced that *Poria* contains terpenes, sterols, pachymaran, fatty acids, volatile oil, and some inorganic elements, and the effective active components are mainly triterpenes and pachymaran. The triterpenes make up most of the *Poria* [9], while pachymaran accounts for the majority of the sclerotia (over 80%) in dry *Poria* [7].

2.1. Terpenoids. In 1939, Japanese scientists boiled the mixture of *Poria* with pyridine, acetic anhydride, and some other compounds in methanol and obtained one triterpene substance, pachymic acid (1) [10]. Subsequently, a new triterpene compound, dehydrotrametenolic acid (39), was found in *Poria* sclerotia in 1970 [11], and ganoderic acid (11) was isolated from *Poria* powder in 1998 [12]. So far, a total of 163 terpenoids have been identified, and they are mainly triterpenoids, diterpenoids, and sterols. According to the basic skeleton, 4 categories of terpenoids in *Poria*, lanoster-8-ene triterpenes, lanoster-7,9(11)-diene triterpenes, 3,4-ring-opening lanoster-8-ene triterpenes, and 3,4-ring-opening lanoster-7,9(11)-diene triterpenes [13] are separated as shown in Table 1. Besides, their molecular structures are presented in Figure 1.

2.2. Polysaccharides. Polysaccharides account for 70%~90% of the dry weight of *Poria*, and until now, 35 kinds of PAC from *Poria* have been reported (Table 2) [63]. Many scholars have found that the physicochemical properties and biological activities of polysaccharides would change to a certain extent after the chemical modification or the introduction of some specific chemical groups [64], which are taken as one efficient way to treat some human diseases [65–67].

2.3. Other Compounds. Besides triterpenes and polysaccharides, there are some other components in *Poria*, mainly including octanoic acid, lauric acid, undecanoic acid, fatty acid, palmitic acid, carotene, choline, adenine [1, 16], and some inorganic elements such as calcium, magnesium, iron, sodium, manganese, etc.

3. Bioactivity of *Poria*

In this paper, articles related to the pharmacological activity of *Poria* after 2011 were selected as references. And its pharmacological effects are summarized (Table 3).

3.1. Antitumor Action. The antitumor effect of *Poria* has been attracting many researchers for a long time. Many studies found that triterpenes and polysaccharides in *Poria* had obvious antitumor activity, especially to the colon cancer cells, lung adenocarcinoma cells, kidney cancer cells, human prostate cancer cells, cervical cancer cells, and human breast cancer cells.

3.1.1. The Antitumor Effect of Poria Triterpenes. Lin proved that total triterpenes of *Poria* had a significant inhibitory effect on the RKO cell line by inducing apoptosis through caspase 9 and caspase 3 activated by the combination of Cyt C and Apaf-1 [68]. Triterpenes from *Poria* could inhibit the proliferation of the A549 cell line by increasing the protein expression levels of Nrf2, GST, and NQO1 [69]. PA induced apoptosis of human renal cell carcinoma 786–0 cell line by inhibiting the activation of the Wnt signaling pathway [70]. PA could inhibit the expression of trim29 mRNA, activate caspase-9, and inhibit the expression of cyclin D1, which indicated that PA could induce apoptosis of Caski cells through inhibition [71]. Jiang found that PA could promote the apoptosis of human breast cancer MDA-MB-231 cells by enhancing the activity of caspase and the expression of cleaved PARP [72]. *Poria* ethanol extract could induce apoptosis by decreasing the expression of Bcl-2 and increasing the expression of Bax, increasing the content of cytoplasm, the active forms of cleaved caspase-9 and caspase-3, and cleaved PARP, which proved that pachymic acid had an inhibitory effect on MDA-MB-231 cells. *Poria* ethanol extract treatment alleviated the damage to the liver and normalized the serum levels of ALT and AST in mice compared with the mice with cisplatin treatment [73]. The study showed that PA could induce apoptosis of SGC-7901 cells by inactivating the JAK2/STAT3 signaling pathway, which proved that PA was a potential bioactive substance for the treatment of gastric cancer [74]. PA could induce caspase 3-mediated apoptosis of HOS and primary osteosarcoma cells by increasing PTEN expression and inhibiting Akt activation [75].

3.1.2. The Antitumor Effect of PAC. Tang proved that PAC could inhibit the phosphorylation of the ERK signaling pathway by downregulating the expression of *p*-ERK1/2, which indicated that PAC could inhibit the proliferation and promote apoptosis of HeLa cells [52]. Lin et al. demonstrated that FMGP inhibited the migration of lung cancer CL1-5 cells by downregulating TGFβRI expression and simultaneously decreasing the phosphorylation levels of FAK and Akt [53]. CMP3 induced HepG2 cell apoptosis through two pathways. The first pathway was to promote HepG2 cell apoptosis by upregulating the release of pro-apoptotic proteins Bax, Caspase-3, p53, and cyto C. The other pathway was to upregulate the expression of Fas, FasL, and FADD mRNA, and promote the expression of caspase-3, caspase-8, and caspase-9 [54]. PPSW-1 and Sul-W-1 inhibit the migration of MDA-MB-231 cells by inhibiting SATB1 gen [56].

In summary, *Poria* plays an antitumor role mainly by inhibiting tumor cell proliferation, inducing cell apoptosis, and inhibiting tumor cell metastasis.

3.2. Immune Regulation. *Poria* also has immunological activity in vitro and in vivo. Triterpenes and polysaccharides from *Poria* were found with extensive immunomodulatory effects and could improve the immune function of the body. Xie et al. study showed that total triterpenes of *Poria* could reduce the metabolic activity of spleen cells in mice stimulated by LPS and Con A and reduce the levels of IgG, IgM, IL-2, and IFN-γ. Total triterpenes can reduce the levels of serum hemolysin and IL-4 in humoral immune response model mice. The spleen index was decreased in high doses (400 mg/kg) and medium doses (200 mg/kg), indicating that total triterpenes had inhibitory effects on the immune function of mice in vitro and in vivo [76]. Wang et al. study showed that S-CMP could significantly reduce the content of MDA and significantly increase the titer of serum hemolysin antibody and the production of spleen antibody. This

Table 1: Terpenoids isolated from *Poria*.

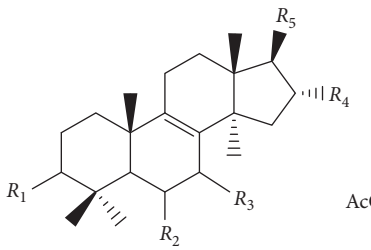
No.	Name	Ref.
Lanoster-8-ene triterpenes (1–38)		
(1)	Pachymic acid	[14]
(2)	Tumulosic acid	[14]
(3)	Trametenolic acid	[9]
(4)	Eburicoic acid	[9]
(5)	3-O-acetyl-16α-hydroxytrametenolic acid	[15]
(6)	16α-Hydroxytrametenolic acid	[16]
(7)	O-acetylpachymic acid	[12]
(8)	O-acetylpachymic acid-25-ol	[12]
(9)	Methyl-O-acetylpachymate	[12]
(10)	Pachymic acid methyl ester	[12]
(11)	Ganoderic acid	[12]
(12)	25-Hydroxypachymic acid	[16]
(13)	25-Hydroxy-3-epitumulosic acid	[17]
(14)	16α,25-Dihydroxyeburiconic acid	[17]
(15)	16α-Hydroxyeburiconic acid	[17]
(16)	3β,16α-Dihydroxy-7-oxo-24-methyllanosta-8,24(31)-dien-21-oic acid	[18]
(17)	3α,16α-Dihydroxy-7-oxo-24-methyllanosta-8,24(31)-dien-21-oic acid	[18]
(18)	Oxotrametenolic acid	[19]
(19)	Acetyl eburicoic acid	[20]
(20)	Poricoic acid ZH	[2]
(21)	Poricoic acid ZU	[2]
(22)	Poricoic acid ZW	[2]
(23)	3β,15α-Dihydroxy-24-oxolanosta-8-en- 21-oic acid	[16]
(24)	3β-Acetyloxy-16α-hydroxy-24-oxolanost-8-en-21-oic acid	[16]
(25)	Daedaleanic acid B	[16]
(26)	15α-Hydroxyeburiconic acid	[16]
(27)	3α,16α,25-Trihydroxylanosta-8,24-dien- 21-oic acid	[16]
(28)	16α,29-Dihydroxyeburiconic acid	[16]
(29)	3β-Acetyloxy-16α,26-dihydroxylanosta-8,24-dien-21-oic acid	[16]
(30)	15α-Hydroxy-3-oxolanosta-8,24-dien-21-oic acid	[16]
(31)	16α-Hydroxy-3-oxolanosta-8,24-dien-21-oic acid	[16]
(32)	3β,16α-Bis(acetyloxy)-29-hydroxylanosta-8,24-dien-21-oic acid	[16]
(33)	Hispindic acid B	[16]
(34)	3β,15α-Bis(acetyloxy)-24- methylenelanost-8-en-21-oic acid	[16]
(35)	16α-Acetyloxyeburiconic acid	[16]
(36)	3-Epi-pachymic acid	[16]
(37)	Ceanphytamic acid A	[21]
(38)	Ceanphytamic acid B	[21]
Lanoster-7,9(11)-diene triterpenes (39–82)		
(39)	Dehydrotrametenolic acid	[14]
(40)	Dehydropachymic acid	[22]
(41)	Dehydroeburicoic acid	[9]
(42)	6α-Hydroxypolyporenic acid C	[2]
(43)	3-Epi-dehydrotumulosic acid	[15]
(44)	25-Hydroxy-3-epi-dehydrotumulosic acid	[15]
(45)	Dehydrotumulosic acid	[15]
(46)	Dehydroeburiconic acid	[15]
(47)	3-O-Acetyl-16α-hydroxydehydrotrametenolic acid	[15]
(48)	3-Epidehydropachymic acid	[15]
(49)	3β,16α-Dihydroxylanosta-7,9(11),24-trien-21-oic acid	[23]
(50)	6α-Hydroxydehydropachymic acid	[16]
(51)	3β-p-Hydroxybenzoyldehydrotumulosic acid	[24]
(52)	3β-Hydroxy-16α-acetoxy-lanosta-7,9(11),24-trien-21-oic acid	[12]
(53)	Polyporenic acid C	[17]
(54)	Dehydrotrametenonic acid	[23]
(55)	15α-Hydroxydehydrotumulosic acid	[25]
(56)	16α,25-Dihydroxydehydroeburicoic acid	[25]
(57)	29-Hydroxypolyporenic acid C	[16]
(58)	Poriacosones A	[26]

Table 1: Continued.

No.	Name	Ref.
(59)	Poriacosones B	[26]
(60)	16α,27-Dihydroxydehydrotrametenoic acid	[17]
(61)	3β,16α,30-Trihydroxy-24-methyllanosta-7,9(11),24(31)-trien-21-oic acid	[18]
(62)	3β-Acetoxy-16α,24β-dihydroxylanosta-7,9(11),25-trien-21-oic acid	[18]
(63)	29-Hydroxydehydrotumulosic acid	[27]
(64)	29-Hydroxydehydropachymic acid	[28]
(65)	3β,15α-Dihydroxylanosta-7,9(11),24-triene-21-oic acid	[29]
(66)	Dehydrosulphurenic acid	[29]
(67)	Dehydroeburicoic acid monoacetate	[18]
(68)	3β-Acetoxylanosta-7,9(11),24-trien-21-oic acid	[18]
(69)	Poricoic acid ZE	[2]
(70)	Poricoic acid ZI	[2]
(71)	Poricoic acid ZL	[2]
(72)	Poricoic acid ZV	[2]
(73)	Coriacoic acid B	[30]
(74)	Coriacoic acid C	[30]
(75)	6,16α-Dihydroxydehydrotrametenonic acid	[16]
(76)	16α-Hydroxydehydrotrametenonic acid	[16]
(77)	25,26-Dihydroxydehydropachymic acid	[16]
(78)	3β,16α-Dihydroxy-24-hydroxymethyllanosta-7,9(11)-dien-21-oic acid	[16]
(79)	15α-Hydroxydehydrotrametenolic acid	[16]
(80)	16α-Hydroxydehydrotrametenoic acid	[16]
(81)	16-Hydroxy-3,24-dioxolanosta-7,9(11)-dien-21-oic acid	[16]
(82)	16α-Acetyloxy-24-methylene-3-oxolanosta-7,9(11)-dien-21-oic acid	[16]
3,4-Ring-opening lanoster-8-ene triterpenes (83–93)		
(83)	Poricoic acid G	[26]
(84)	Poricoic acid H	[26]
(85)	25-Hydroxyporicoic acid H	[25]
(86)	Poricoic acid GM	[17]
(87)	Poricoic acid HM	[17]
(88)	Poricoic acid GE	[29]
(89)	Poricoic acid ZA	[31]
(90)	Poricoic acid ZJ	[2]
(91)	Poricoic acid ZK	[2]
(92)	Poricoic acid ZR	[21]
(93)	25-Methoxy-29-hydroxyporicoic acid HM	[16]
3, 4-Ring-opening lanoster-7,9(11)-diene triterpenes (94–122)		
(94)	Poricoic acid A	[27]
(95)	Poricoic acid B	[27]
(96)	Poricoic acid C	[24]
(97)	Poricoic acid D	[24]
(98)	Poricoic acid DM	[24]
(99)	Poricoic acid AM	[24]
(100)	Poricoic acid E	[15]
(101)	Poricoic acid BM	[15]
(102)	Poricoic acid F	[15]
(103)	16-Deoxyporicoic acid B	[25]
(104)	Poricoic acid CM	[25]
(105)	25-Methoxyporicoic acid A	[17]
(106)	26-Hydroxyporicoic acid DM	[17]
(107)	25-Hydroxyporicoic acid C	[17]
(108)	Poricoic acid AE	[32]
(109)	Poricoic acid CE	[32]
(110)	3,4-Secolanosta-4(28),7,9,24Z-tetraen-3,26-dioic acid	[33]
(111)	Poricoic acid BE	[29]
(112)	16α-Hydroxy-3,4-secolanosta-4(28),7,9(11),24(31),25(27)-pentaene-3,21-dioic acid	[29]
(113)	Poricoic acid ZB	[2]
(114)	Poricoic acid ZC	[21]
(115)	Poricoic acid ZD	[21]
(116)	Poricoic acid ZG	[21]

Table 1: Continued.

No.	Name	Ref.
(117)	Poricoic acid ZM	[21]
(118)	Poricoic acid ZO	[21]
(119)	Poricoic acid ZP	[21]
(120)	Poricoic acid ZN	[21]
(121)	Poricoic acid ZT	[2]
(122)	Poricoic acid ZQ	[21]
Cyclodioxy tetracyclic triterpenes (123, 124)		
(123)	5α,8α-Peroxydehydrotumulosic acid	[25]
(124)	3-(2-Hydroxyacetoxy)-5α,8α-peroxydehydrotumulosic acid	[34]
4, 5-ring-opening triterpenes (125, 126)		
(125)	Daedaleanic acid A	[35]
(126)	11β-Ethoxydaedaleanic acid A	[21]
Other tetracyclic triterpenoids (127–131)		
(127)	(3β,16α)-3-Acetyloxy-16-hydroxy-24-methylenelanosta-5,7(9),11-tetraene-21-oic acid	[29]
(128)	16α-Hydroxy-3-oxo-24-methyllanosta-5,7,9(11),24(31)-tetraen-21-oic acid	[18]
(129)	6,7-Dehydroporicoic acid H	[17]
(130)	Coriacoic acid A	[30]
(131)	Coriacoic acid D	[30]
Pentacyclic triterpenes (132–134)		
(132)	β-Amyrin acetate	[12]
(133)	Oleanolic acid	[36]
(134)	3-O-acetyloleanolic acid	[1]
Diterpenes (135–140)		
(135)	7-oxo-15-Hydroxydehydroabietic acid	[16]
(136)	Dehydroabietic acid methyl ester	[37]
(137)	Poricoic acid ZF	[2]
(138)	Dehydroabietic acid	[2]
(139)	7-Oxocallitrisic acid	[2]
(140)	Pimaric acid	[2]
Sterols (141–162)		
(141)	Ergosterol	[1]
(142)	(22E)-ergosta-5,7,9(11),22-tetraen-3β-ol	[1]
(143)	Ergosta-5,7-dien-3β-ol	[1]
(144)	(22E)-Ergosta-8(14),22-dien-3β-ol	[1]
(145)	(22E)-Ergosta-6,8(14),22-trien-3β-ol	[1]
(146)	(22E)-Ergosta-7,22-dien-3β-ol	[16]
(147)	Ergost-7-en-3β-ol	[1]
(148)	Ergosterol peroxide	[2]
(149)	Daucosterol	[38]
(150)	Cerevisterol	[20]
(151)	Biemnasterol	[1]
(152)	B-Sitosterol	[38]
(153)	3β,5α-Dihydroxy-ergosta-7,22-diene-6-one	[1]
(154)	3β,5α,9α-Trihydroxy-ergosta-7,-dien-6-one	[1]
(155)	Ergosta-7,22-diene-3-one	[1]
(156)	6,9-Epoxy-ergosta-7,22-diene-3-ol	[1]
(157)	Ergosta-4,22-diene-3-one	[1]
(158)	Ergosta-5,6-epoxy-7,22-dien-3-ol	[36]
(159)	Pregn-7-ene-2β,3α,15α,20-tetrol	[2]
(160)	Peroxy-ergosterol	[2]
(161)	Ergot sterone	[2]
(162)	9,11-Dehydroergosterol peroxide	[2]



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3 R_1 = β -OH R_2 = α-H R_3 = H R_4 = α -H R_5 = b
4 R_1 = β -OH R_2 = H R_3 = H R_4 = α -H R_5 = a
5 R_1 = β -OAc R_2 = α -H R_3 = H R_4 = α -OH R_5 = b
6 R_1 = β -OH R_2 = α -OH R_3 = H R_4 = α -OH R_5 = b
7 R_1 = β -OAc R_2 = H R_3 = H R_4 = α -OAc R_5 = a
12 R_1 = β -OAc R_2 = H R_3 = H R_4 = α -OH R_5 = e
13 R_1 = α -OH R_2 = H R_3 = H R_4 = α -OH R_5 = e
14 R_1 = = O R_2 = H R_3 = H R_4 = α -OH R_5 = e
15 R_1 = = O R_2 = H R_3 = H R_4 = α -OH R_5 = e
16 R_1 = β -OH R_2 = H R_3 = = O R_4 = α -OH R_5 = a
17 R_1 = α -OH R_2 = H R_3 = = O R_4 = α -OH R_5 = a
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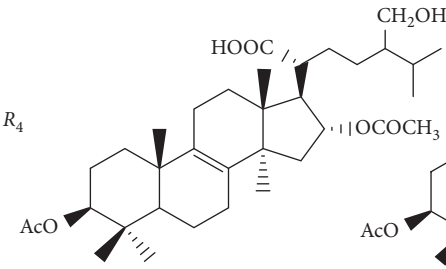

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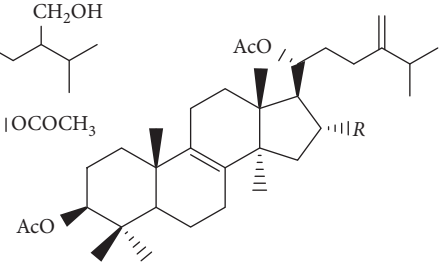

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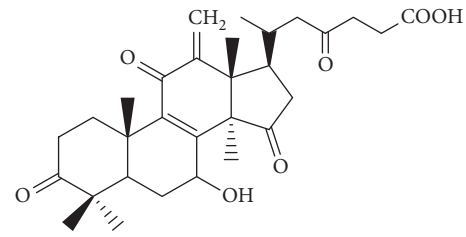

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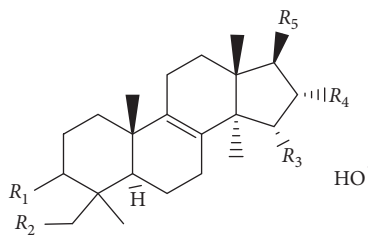

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25 R_1 = α -OH R_2 = H R_3 = H R_4 = OH R_5 = c′
26 R_1 = = O R_2 = H R_3 = OH R_4 = H R_5 = c′
27 R_1 = α -OH R_2 = H R_3 = H R_4 = OH R_5 = d′
28 R_1 = = O R_2 = OH R_3 = H R_4 = OH R_5 = a′
29 R_1 = β -OAc R_2 = H R_3 = H R_4 = OH R_5 = d′
30 R_1 = = O R_2 = H R_3 = OH R_4 = H R_5 = b′
31 R_1 = = O R_2 = H R_3 = H R_4 = OH R_5 = b′
32 R_1 = β -OAc R_2 = OH R_3 = H R_4 = OAc R_5 = b′
33 R_1 = β -OH R_2 = OH R_3 = H R_4 = H R_5 = a′
34 R_1 = β -OAc R_2 = H R_3 = OAc R_4 = H R_5 = a′
35 R_1 = = O R_2 = H R_3 = H R_4 = OAc R_5 = a′
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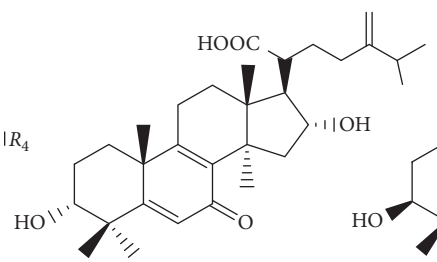

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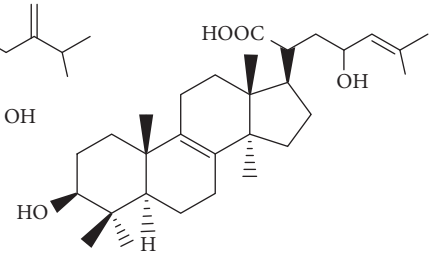

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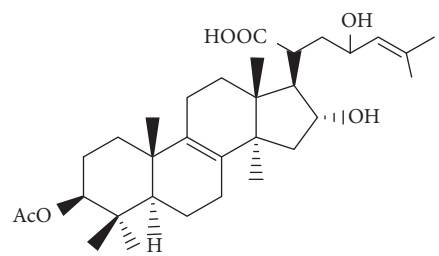
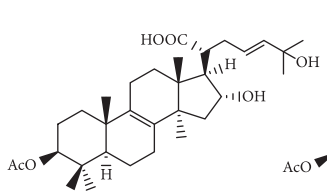


22

(a)

Figure 1: Continued.



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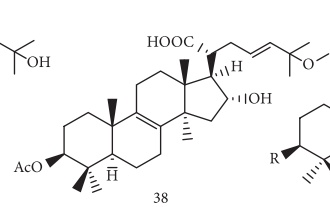

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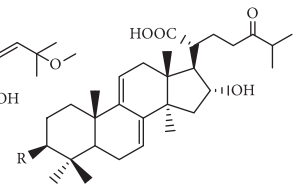
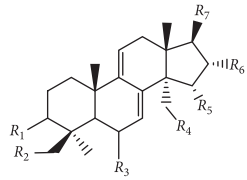
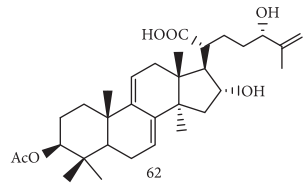


58 R_1 = α -OH R_2 = c
59 R_1 = β -OH R_2 = c
60 R_1 = α -OH R_2 = d



39 R_1 = β -OH R_2 = H R_3 = H R_4 = H R_5 = α -H R_6 = α -H R_7 = b′
40 R_1 = β -OAc R_2 = H R_3 = α -H R_4 = H R_5 = H R_6 = α -OH R_7 = a
41 R_1 = β -OH R_2 = H R_3 = α-H R_4 = H R_5 = H R_6 = α -H R_7 = a
42 R_1 = = O R_2 = H R_3 = α -OH R_4 = H R_5 = H R_6 = α -OH R_7 = e′
43 R_1 = α -OH R_2 = H R_3 = H R_4 = H R_5 = H R_6 = α -OH R_7 = a
44 R_1 = α -OH R_2 = H R_3 = H R_4 = H R_5 = H R_6 = α -OH R_7 = e
45 R_1 = β -OH R_2 = H R_3 = α -H R_4 = H R_5 = H R_6 = α -H R_7 = a
46 R_1 = = O R_2 = H R_3 = α -H R_4 = H R_5 = H R_6 = α -H R_7 = a′
47 R_1 = β -OAc R_2 = H R_3 = H R_4 = H R_5 = α -H R_6 = α -OH R_7 = b′
48 R_1 = α -OAc R_2 = H R_3 = H R_4 = H R_5 = H R_6 = α -OH R_7 = a
49 R_1 = β -OH R_2 = H R_3 = H R_4 = H R_5 = α -H R_6 = α -OH R_7 = b′
50 R_1 = β -OAc R_2 = H R_3 = α -OH R_4 = H R_5 = H R_6 = α -OH R_7 = a
51 R_1 = β -p-hydroxybenzoyl R_2 = H R_3 = α -H R_4 = H R_5 = H R_6 = α -OH R_7 = a
52 R_1 = β -OH R_2 = H R_3 = H R_4 = H R_5 = α -H R_6 = α -OAc R_7 = b′
53 R_1 = = O R_2 = H R_3 = α -OH R_4 = H R_5 = H R_6 = α -OH R_7 = e′
54 R_1 = = O R_2 = H R_3 = H R_4 = H R_5 = H R_6 = H R_7 = b
55 R_1 = β -OH R_2 = H R_3 = H R_4 = H R_5 = α -OH R_6 = α -OH R_7 = a′
56 R_1 = = O R_2 = H R_3 = α-H R_4 = H R_5 = H R_6 = α -OH R_7 = e′
57 R_1 = = O R_2 = OH R_3 = α-H R_4 = H R_5 = H R_6 = α -OH R_7 = a′
61 R_1 = α -OH R_2 = H R_3 = H R_4 = OH R_5 = H R_6 = α -OH R_7 = a
63 R_C-OH R_2 = OH R_3 = H R_4 = H R_5 = H R_6 = α -OH R_7 = a
64 R_1 = α -OAc R_2 = OH R_3 = H R_4 = H R_5 = H R_6 = α -OH R_7 = a
65 R_1 = β -OH R_2 = H R_3 = H R_4 = H R_5 = α -OH R_6 = α -H R_7 = a′
66 R_1 = β -OH R_2 = H R_3 = H R_4 = H R_5 = α -OH R_6 = α -H R_7 = b′
67 R_1 = α-OAc R_2 = H R_3 = H R_4 = H R_5 = H R_6 = α -H R_7 = a
68 R_1 = β -OAc R_2 = H R_3 = H R_4 = H R_5 = α -H R_6 = α -H R_7 = b′
70 R_1 = = O R_2 = H R_3 = β -OH R_4 = H R_5 = H R_6 = α -OH R_7 = c′



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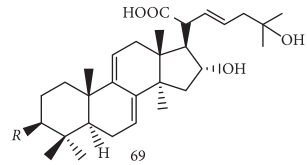

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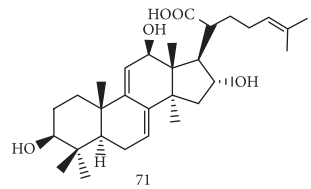

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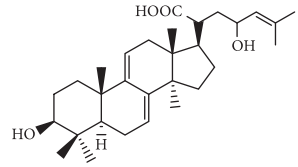

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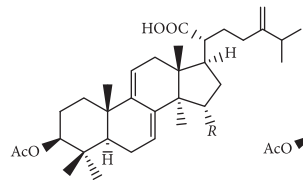
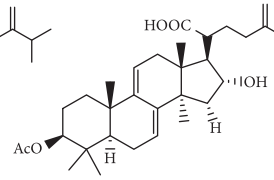
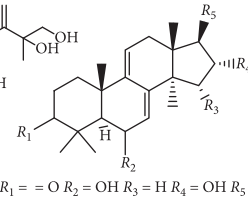


73 R = OAc
74 R = OH



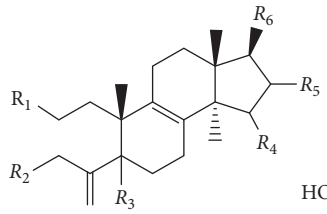
77



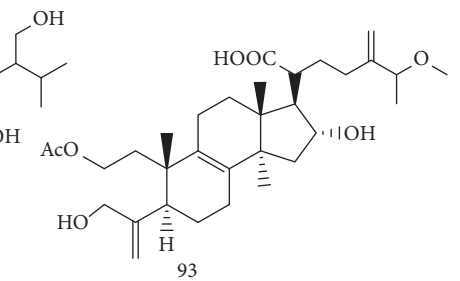
75 R_1 = = O R_2 = OH R_3 = H R_4 = OH R_5 = b′
76 R_1 = = O R_2 = H R_3 = H R_4 = OH R_5 = b′
78 R_1 = α -OH R_2 = H R_3 = OH R_4 = H R_5 = b′
80 R_1 = α -OH R_2 = H R_3 = H R_4 = OH R_5 = b′
81 R_1 = = O R_2 = H R_3 = H R_4 = OAc R_5 = c′
82 R_1 = = O R_2 = H R_3 = H R_4 = OH R_5 = a′

(b)

Figure 1: Continued.

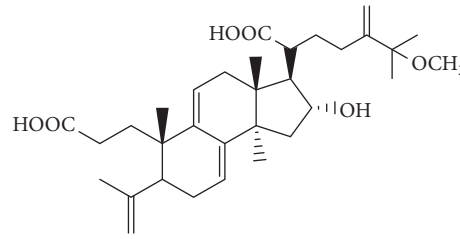


83 R_1 = COOH R_2 = H R_3 = H R_4 = H R_5 = α -OH R_6 = b′
84 R_1 = COOH R_2 = H R_3 = H R_4 = H R_5 = α -OH R_6 = a
85 R_1 = COOH R_2 = H R_3 = H R_4 = H R_5 = α -OH R_6 = e
86 R_1 = $COOCH_3$ R_2 = H R_3 = H R_4 = H R_5 = α -OH R_6 = b′
87 R_1 = $COOCH_3$ R_2 = H R_3 = H R_4 = H R_5 = α -OH R_6 = a
88 R_1 = $COOCH_2CH_3$ R_2 = H R_3 = H R_4 = H R_5 = α -OH R_6 = b′
89 R_1 = COOH R_2 = H R_3 = H R_4 = H R_5 = α -OH R_6 = d
90 R_1 = COOH R_2 = H R_3 = α -H R_4 = α -OH R_5 = H R_6 = a′
91 R_1 = $COOCH_3$ R_2 = H R_3 = α -H R_4 = H R_5 = α -OH R_6 = b′
92 R_1 = $COOCH_3$ R_2 = H R_3 = α -H R_4 = H R_5 = α -OH R_6 = d′



78

93



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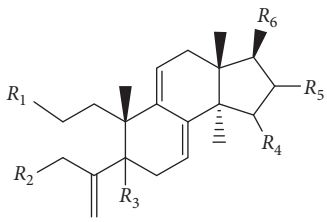
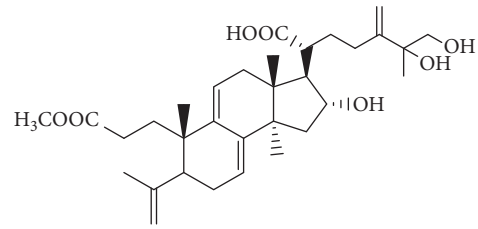


94 R_1 = COOH R_2 = H R_3 = H R_4 = H R_5 = α -OH R_6 = a′
95 R_1 = COOH R_2 = H R_3 = H R_4 = H R5 = α -OH R_6 = b′
96 R_1 = COOH R_2 = H R_3 = H R_4 = H R_5 = α -H R_6 = a′
97 R_1 = COOH R_2 = H R_3 = H R_4 = H R_5 = α -OH R_6 = b′
98 R_1 = $COOCH_3$ R_2 = H R_3 = H R_4 = H R_5 = α -OH R_6 = b′
99 R_1 = $COOCH_3$ R_2 = H R_3 = H R_4 = H R_5 = α -OH R_6 = a′
100 R_1 = COOH R_2 = H R_3 = H R_4 = H R_5 = α -OH R_6 = d′
101 R_1 = $COOCH_3$ R_2 = H R_3 = H R_4 = H R_5 = α -OH R_6 = b′
102 R_1 = COOH R_2 = OH R_3 = H R_4 = H R_5 = α -OH R_6 = a′
103 R_1 = COOH R_2 = H R_3 = H R_4 = H R_5 = α -H R_6 = b′
104 R_1 = $COOCH_3$ R_2 = H R_3 = H R_4 = H R_5 = α -H R_6 = a′
107 R_1 = COOH R_2 = H R_3 = H R_4 = H R_5 = α -H R_6 = b′
108 R_1 = $COOCH_2CH_3$ R_2 = H R_3 = H R_4 = H R_5 = α -OH R_6 = a′
109 R_1 = $COOCH_2CH_3$ R_2 = H R_3 = H R_4 = H R_5 = α -H R_6 = a′
111 R_1 = $COOCH_2CH3$ R_2 = H R_3 = H R_4 = H R_5 = α -OH R_6 = b′
114 R_1 = COOH R_2 = OH R_3 = α -H R_4 = H R_5 = α -OH R_6 = b′
119 R_1 = $COOCH_3$ R_2 = OH R_3 = α -H R_4 = H R_5 = α -OH R_6 = a′
120 R_1 = COOH R_2 = H R_3 = α -H R_4 = α -H R_5 = H R_6 = a′
122 R_1 = $COOCH_3$ R_2 = OH R_3 = α -H R_4 = H R_5 = α -OH R_6 = a′



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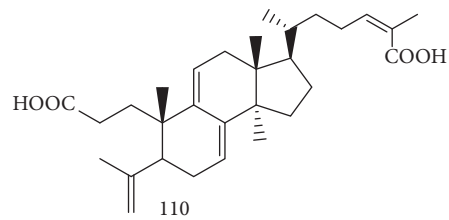

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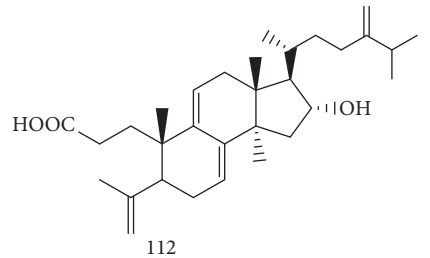
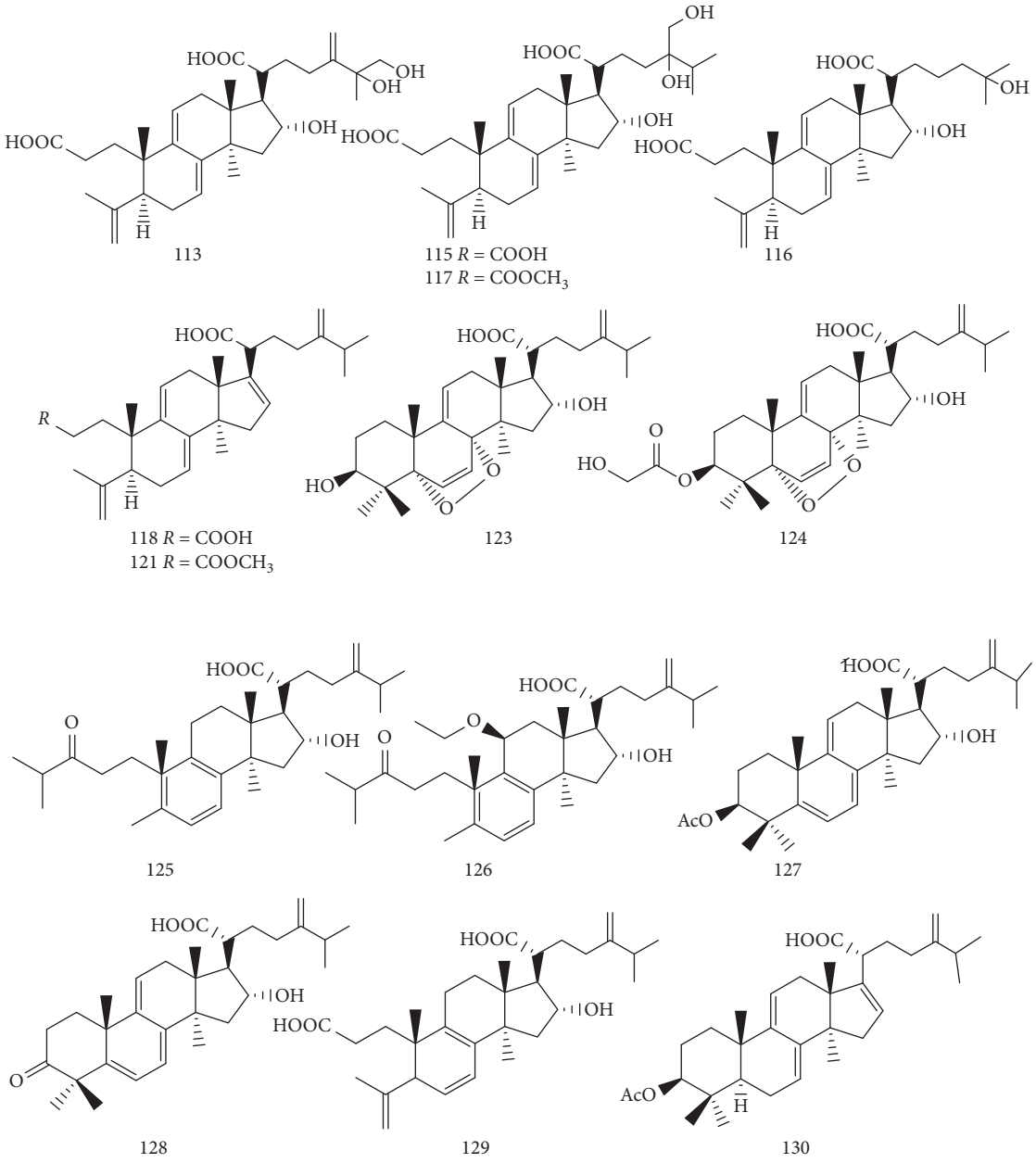


112

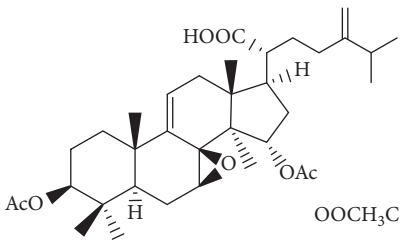
(c)

Figure 1: Continued.



(d)

Figure 1: Continued.



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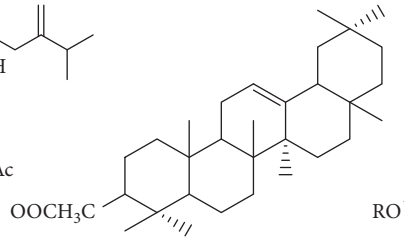

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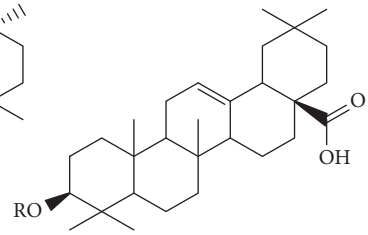
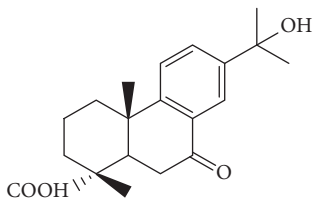


133 R = OH
134 R = OAc



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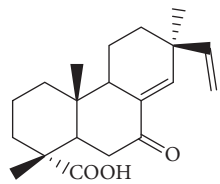

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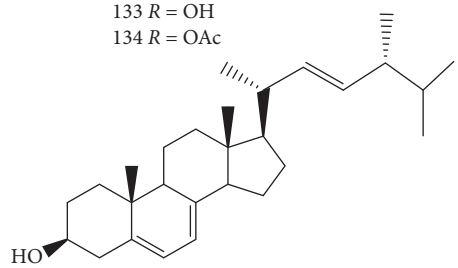

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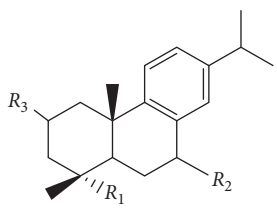
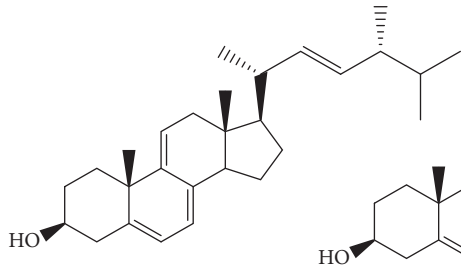


136 R_1 = α -$COOCH_3$ R_2 = H R_3 = H
137 R_1 = H R_2 = $O(CH_2)_7CH_3$ R_3 = COOH
138 R_1 = α -COOH R_2 = R_3 = H
139 R_1 = α -COOH R_2 = = O R_3 = H



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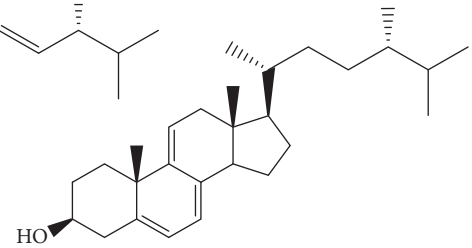

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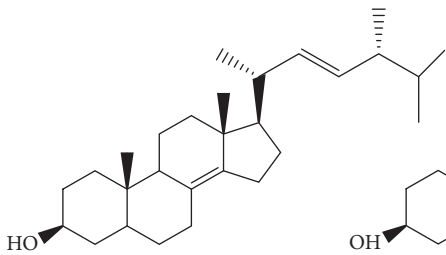

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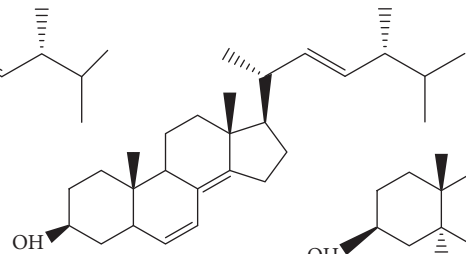

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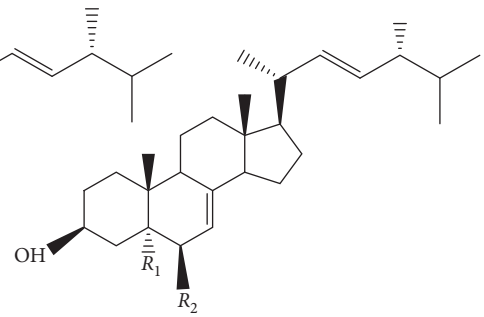

146 R_1 = R_2 = H
150 R_1 = R_2 = OH

(e)

Figure 1: Continued.

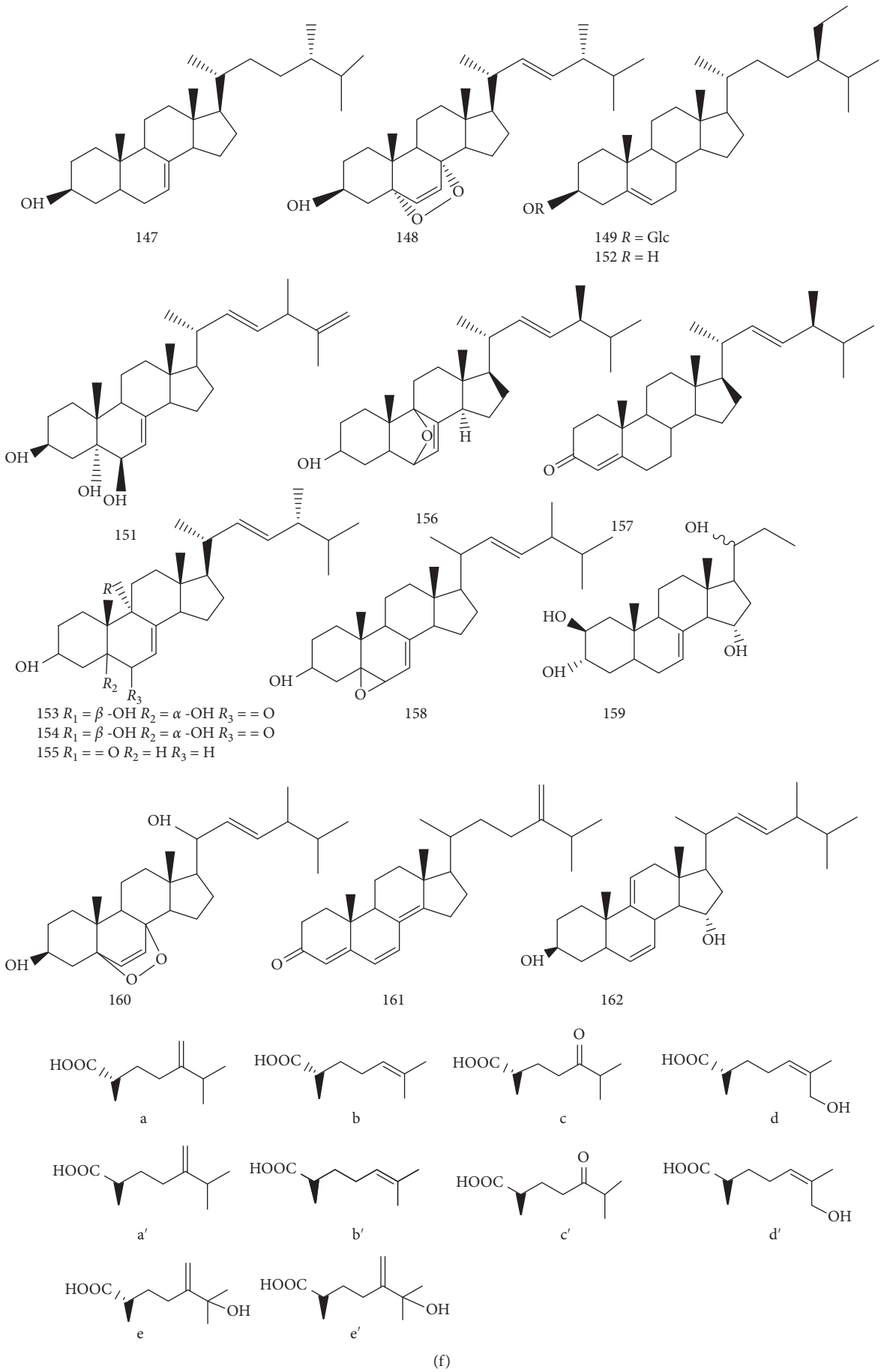

Figure 1: Structures of terpenoids isolated from *Poria*.

Table 2: Polysaccharides isolated from *Poria*.

No.	Name	Ref.
(1)	Pachyman	[39]
(2)	PolysaccharideH11	[40]
(3)	PC1, PC2, PC2-A	[40]
(4)	PC3	[40]
(5)	PC4	[41]
(6)	PCSC22	[24]
(7)	PCM1, PCM2	[24]
(8)	PCM3	[24]
(9)	PCM4	[42]
(10)	ac-PCM0, ac-PCM1, ac-PCM2, PCPWP, PCPWPS	[42]
(11)	ac-PCM3-I, ac-PCM3-II	[42]
(12)	ac-PCM4-I, ac-PCM4-II	[43]
(13)	wb-PCM1, wb-PCM2, wc-PCM1, wc-PCM2	[42]
(14)	wb-PCM3-I, wc-PCM3-I, wb-PCM3-II, wb-PCM4-I, wb	[21]
(15)	PCM4-II, wc-PCM3-II, wc-PCM4I, wc-PCM4-II, WIP	[43]
(16)	wb-PCM0, wc-PCM0	[44]
(17)	ab-PCM0, ab-PCM1, ab-PCM2-I, ab-PCM2-I, ab-PCM3-I	[44]
(18)	ab-PCM3-II, ab-PCM4-I, abPCM4-II	[45]
(19)	PCS1, PCS2, PCS3-I	[45]
(20)	PCS3-II	[45]
(21)	PCS4-I	[45]
(22)	PCS4-II	[46]
(23)	PC-PS	[24]
(24)	PCSG	[47]
(25)	Pi-PCM0, Pi-PCM1, Pi-PCM2	[47]
(26)	Pi-PCM3-I, Pi-PCM4-I	[47]
(27)	Pi-PCM3-II	[47]
(28)	Pi-PCM4-II	[48]
(29)	Polysaccharides from *Poria*	[24]
(30)	WSP, WSP-1, WSP-2	[24]
(31)	PCII	[24]
(32)	PCP	[49]
(33)	ATPCP	[50]
(34)	PCP-II	[24]
(35)	CMP33	[51]
(36)	PAC	[52]
(37)	FMGP	[53]
(38)	CMP3	[54]
(39)	PPS, CMP	[55]
(40)	PPSW-1, Sul-W-1	[56]
(41)	S-CMP	[57]
(42)	Polysaccharides (WRP)	[58]
(43)	PPC	[59]
(44)	PCP-M	[60]
(45)	Sulfated pachymaran	[61]
(46)	PCWPW and PCWPS	[62]

indicated that S-CMP had a good immune activity [57]. The results of TIAN showed that *Poria* polysaccharide could exert immunomodulatory activity through TLR4/TRAF6/NF-κB signaling pathway [77]. Pu et al. found that *Poria* polysaccharide could exert immunomodulatory effects in Ca^{2+}/PKC/p38/NF-κB signaling pathway [78].

All of the above studies confirm that *Poria* played an immunological regulatory role through various ways, which can lay a solid foundation for subsequent studies on immunity and benefit the exploitation of potential clinical application value.

3.3. Effects on Kidney. Studies have found that *Poria* can effectively resist renal injury, and the protection of diabetic nephropathy is a research hotspot. Li et al. study found that *Poria* polysaccharide treatment group could reduce serum IL-6 and TGR-β1 in DN rats ($P < 0.01$), reduce inflammatory infiltration, and protect kidney tissue to a certain extent [79]. Wu et al. experiment showed that *Poria* polysaccharides could reduce hepatocyte apoptosis and inflammatory stress by inhibiting the NF-κB pathway, which indicated that *Poria* polysaccharides had a protective effect on acetaminophen-induced liver injury in mice [80]. Another experiment showed that WRP could enhance the antioxidant level by increasing superoxide dismutase and glutathione peroxidase and significantly reducing malondialdehyde level in mice kidney tissue. Another experiment showed that WRP could significantly reduce malondialdehyde level and enhance the antioxidant level of the body through increasing superoxide dismutase and glutathione peroxidase in kidney tissue of type 2 diabetic mice, and reduce the expression of the Bax gene in kidney tissue and reduce the apoptosis of renal tissue cells [58]. Zhang et al. experiment showed that WRP could inhibit the expression of the Bax gene in kidney tissue of type 2 diabetic mice and reduce the apoptosis of renal tissue cells. The mechanism of action still needs further study [81]. PPC could increase uric acid excretion by upregulating rOAT1 expression and downregulating rURAT1 expression. It was proved that PPC had anti-hyperuricemia activity [59].

Chen et al. study showed that Poricoic acid ZC (115), Poricoic acid ZD (116), and Poricoic acid ZE (69) could prevent tubulointerstitial fibrosis by blocking the interaction between TGFbR1 and Smad3, selectively inhibiting TGFβ1 and vaso-induced Smad3 phosphorylation [82]. Another of their experiments found that Poricoic acid ZG (117) and Poricoic acid ZH (20) could reduce renal fibrosis by inhibiting the TGF-β/Smad pathway [83]. The above triterpenes were isolated for the first time and their activities were explored.

Studies showed that *Poria* had diuretic effect. The results of Yong et al. showed that poricoic acid A (94) had a significant diuretic effect on rats with water retention. The results showed that the urine volume of the poricoic acid A group was greater than the spironolactone group in the first hour, indicating that the effect of poricoic acid A was good for the diuretic effect. Reabsorption of electrolyte Na^+ and water increases urination [84]. Ni et al. selected triterpenoids extracted from *Poria* as ligands and selected three aquaporins AQP1, 4, 5 as target proteins. The results of screening with software and molecular docking showed that methyl dehydroabietate had a strong binding activity with AQP1, 4, and 5, respectively. It was speculated that dehydroabietic acid methyl ester (137) could be the active substance of *Poria* for diuresis and spleen strengthening, which provided a reference for the follow-up study of active ingredients [85]. Intravenous injection of *Poria* aqueous extract (1.5 g/kg)

Table 3: Summary table of *Poria cocos* activity.

Type of the activities	Subjects	Activities	Mechanisms	Ref.
Antitumor action	Total triterpenoids	In vitro, the concentration of 80 μg/mL extract could induce RKO cell line apoptosis, IC_{50} was 34.14 μg/mL	Inhibits the proliferation of colon cancer RKO cells and induces the apoptosis of colon cancer RKO cells through the mitochondrial apoptosis pathway	[68]
	Triterpenes	In vitro, the concentration of 30 μg/mL extract could inhibit the proliferation of A549 cell line, IC_{50} was 109.9 μg/mL	Inhibition of the Nrf2-ARE signaling pathway can prolong the duration of metastasis from early to advanced lung cancer	[69]
	PA	In vitro, compared with 0 μg/mL group, 10, 20, 40, and 80 μg/mL groups could significantly increase the apoptosis rate of 786–0 renal carcinoma cells	Inhibition of Wnt signaling pathway induced apoptosis in 786–0 renal carcinoma cells	[70]
	PA	In vitro, 20.0 μmol/L PA promoted the apoptosis of Caski cells	Inhibit the survival of cervical cancer Caski cells and promote apoptosis by inhibiting TRIM29 expression and downregulating Wnt pathway activity	[71]
	PA	In vitro, 1, 2, 5 μmol/L PAC inhibited the proliferation and induced apoptosis of MDA-MB-231 cells	The mechanism of action is related to the activation of PARP	[72]
	Poria ethanol extract	*Poria* ethanol extract (at 150 μg/mL) could induce apoptosis of MDA-MB-231 cells with IC_{50} value of 2.13 ± 0.34 μg/mL	By inducing mitochondria and death receptors to mediate apoptosis; the arrest of the G0/G1 cell cycle promotes apoptosis	[73]
	PA	In vitro, PA inhibited the proliferation of sgc-70901 cells at the concentrations of 0, 20, 40, and 80 μM	Block the G0/G1 cell cycle	[74]
	PA	In vitro, 50 μg/mL PA can significantly reduce the proliferation of osteosarcoma cells	Apoptosis is mediated in part by the PTEN/Akt signaling pathway and caspase 3/7 activity	[75]
	PAC	In vitro, PAC (30, 40, 50 mg/mL) can significantly reduce the migration rate and increase the apoptosis rate of human cancer HeLa cells (IC_{50} is 60 mg/mL)	The proapoptotic mechanism may be related to inhibition of phosphating of the ERK signaling pathway	[52]
	FMGP	In vitro, the concentration of FMGP at 400 μg/mL significantly inhibited the migration of highly metastatic human lung cancer cell line CL1-5 cells	By inhibiting the TGFβRI mediated signaling pathway	[53]
	CMP3	In vitro, the IC_{50} value was 26.34 ± 0.77, and the concentration of CMP3 was 100 μg/mL, which had the highest inhibitory rate on HepG2 cells	Apoptosis is induced through the mitochondrial pathway and the death receptor pathway	[54]
	PPSW-1 and Sul-W-1	The concentration of PPSW-1 and Sul-W-1 at 100 μg/mL had a strong inhibitory effect on the migration of MDA-MB-231 cells in vitro	Inhibition of the expression of the SATB1 gene reduces the migration ability of cancer cells	[56]
Immune regulation	Total triterpenes of *Poria*	Total triterpenes of *Poria* can improve the immune function of mice in vitro (at 40, 20, 10 μg/mL) and in vivo (at 400, 200, 100 mg/kg)	—	[76]
	S-CMP	S-CMP (at 100, 200 mg/kg) showed immunoactivity in BALB/c mice	—	[57]
	Poria polysaccharide	*Poria* polysaccharide has immunomodulatory activity in vivo (at 200 mg/kg) and in vitro (at 200 g/mL)	Immunoregulatory activity is exerted through TLR4/TRAF6/NF-κB signaling pathway in vitro and in vivo	[77]
	Poria polysaccharide	*Poria* polysaccharide had immunomodulatory activity in vitro (at 200 μg/mL)	Immunoregulatory activity is exerted through Ca^{2+}/PKC/p38/NF-κB signaling pathway in macrophages	[78]

Table 3: Continued.

Type of the activities	Subjects	Activities	Mechanisms	Ref.
Effects on kidney	*Poria* polysaccharide	*Poria* polysaccharide (at 50, 100, 200 mg/kg) significantly reduced the inflammatory response of diabetic nephropathy rats in vivo	—	[79]
	Poria polysaccharides	In vivo *Poria* polysaccharides (at 200, 400 mg/kg) had a protective effect on acetaminophen-induced liver injury in mice	Inhibition of hepatocyte apoptosis and inflammatory stress induced by NF-κB pathway plays a protective role in the kidney	[80]
	WRP	In vivo, WRP (200 mg/kg) can inhibit the trend of renal cell apoptosis in the diabetic states	Inhibition of Bax gene overexpression in renal tissue decreased apoptosis of renal cells	[58]
	Pachymaran	Pachymaran can prevent renal interstitial fibrosis in rats with type 2 diabetic nephropathy in vivo at doses of 3, 6, and 12 mg/kg, respectively	—	[81]
	PPC	In vivo, PPC at 2 g/kg has anti-hyperuricemia activity	Uric acid excretion was increased by upregulating rOAT1 expression and downregulating rURAT1 expression	[59]
	Poricoic acid ZC, Poricoic acid ZD, and Poricoic acid ZE	Poricoic acid ZC, poricoic acid ZD, and Poricoic acid ZE can prevent tubulointerstitial fibrosis in vivo (at 10 mg/kg) and in vitro (at 10 μM)	By inhibiting the activation of the Wnt/β-catenin pathway and blocking Smad3 phosphorylation, renal tubulointerstitial fibrosis was reduced	[82]
	Poricoic acid ZG and Poricoic acid ZH	Poricoic acid ZG and poricoic acid ZH (at 10 μM) can inhibit renal fibrosis in vitro	Attenuate renal fibrosis via a Wnt/β-catenin pathway and targeted phosphorylation of smad3 signaling	[83]
	Poricoic acid A	*Poricoic acid A* (at 5, 10, 20 mg/kg) has diuretic activity in vivo	—	[84]
	Dehydroabietic acid methyl ester	The authors found that methyl dehydroabietic acid may be the diuretic substance of *Poria*	—	[85]
	Poria aqueous extract	In vivo, *Poria* aqueous extract can increase the urine volume of rabbits	—	[86]
Hepatoprotective activity	*Poria* polysaccharides	Effects of *Poria* polysaccharides on liver protection against acetaminophen-injured hepatocytes in vitro (at 200 and 400 mg/kg) and in vivo (at 20 and 40 g/L)	Through the molecular mechanisms of reducing hepatocellular inflammatory stress and Hsp90 bioactivity	[87]
	Carboxymethyl pachyman	Carboxymethyl pachyman in vivo (at 50 mg/kg) can alleviate liver injury of CT26 mice induced by 5-FU	Hepatoprotective activity through regulation of NF-κB, Nrf2-ARE and MAPK/P38/JNK pathways	[88]
Effects on blood sugar	Pachymic acid	In vitro pachymic acid (at 1 μM) can increase glucose uptake in 3T3-L1 adipocytes	Hypoglycemic activity through regulation of PI3K and AMPK pathways	[89]
	WRP	WRP (at 200 mg/kg) had hypoglycemic effects on NIDDM mice in vitro	—	[90]
	Insoluble polysaccharide	Insoluble polysaccharide (at 1.0 g/kg and 0.5 g/kg) can improve the symptoms of hyperglycemia in ob/ob mice in vivo	Hypoglycemic activity through regulation of intestinal flora	[91]

Table 3: Continued.

Type of the activities	Subjects	Activities	Mechanisms	Ref.
Antioxidant effects	Carboxymethyl sulfate *Poria* polysaccharide	Carboxymethyl sulfate *Poria* polysaccharide had the strongest scavenging effect on OH and O_2^- and there was an agent-activity relationship. When the sample concentration was 4.5 mg/mL, the scavenging rates of OH and·O_2^- were 79% and 84.2%, respectively, which indicated that the sample had a certain antioxidant activity.	—	[64]
	PCP-M	PCP-M polysaccharides (at 2.0 mg/mL) had antioxidant activity in vitro	—	[60]
	Carboxymethyl-pachyman	In vivo, carboxymethyl-pachyman (at 200 mg/kg) has antioxidant activity	—	[92]
Anti-inflammatory effects	Poricoic acid A	The concentration of 10, 20, 50 μM showed anti-inflammatory activity in vitro	Anti-inflammatory effects through downregulation of iNOS and COX-2 expression and inhibition of NO and PGE2 production	[93]
	PA	In vitro PA (at 25, 50, 100 mg/L) inhibits TNF-α-induced inflammation and oxidative stress damage in SH-SY5Y	It may be a mechanism of action to inhibit apoptosis by downregulating Nrf2 of the ERK/Nrf2 signaling pathway into the nucleus	[94]
	Poricoic acid C	Poricoic acid C (50, 100 μM) had anti-inflammatory activity on RAW264.7 cells stimulated by LPS in vitro	Inhibition of iNOS and COX-2 expression through downregulation of NF-κB exerts anti-inflammatory effects	[30]
	CMP33	CMP33 (62.5–1000 μg/mL) has anti-inflammatory activity in vitro	Anti-inflammatory activity by inhibiting the overproduction of NO, IL-6, TNF-α, and IL-1β in LPS-stimulated RAW264.7 cells	[51]
	Poria polysaccharide	In vivo, *Poria* polysaccharide (at 5, 100, 200 mg/kg) can reduce the infiltration degree of colitis	Anti-inflammatory activity through inhibition of IL-33/ST2 signaling pathway activation	[95]
Effects on the gut	16α-Hydroxytrametenolic Acid	In vitro, 16α-hydroxytrametenolic Acid (60 μM) can improve intestinal barrier function	Improving intestinal barrier function via PI3K/Akt/NF-κB pathway	[96]
	Poria ethanol extract	*Poria* ethanol extract (at 32 g/mL) inhibited intestinal contraction in vitro	Inhibits spontaneous and spastic contractions of the small intestine by inhibiting M receptors and regulating potassium and calcium channels	[97]
	Poria powder and water-soluble polysaccharide	In vivo, *Poria* powder (at 2.0 g/kg) and water-soluble polysaccharide (at 7.6 mg/kg) can protect against intestinal damage caused by cisplatin	Water-soluble polysaccharides exert enteroprotective activity through intestinal flora and metabolic regulation	[16]
	Poria powder	*Poria* powder (at 50 μg/kg) can increase the level of intestinal bifidobacteria in mice in vivo	—	[98]
Antidepressant	Sulfated pachymaran	In vivo, sulfated pachymaran (25 mg/kg, 50 mg/kg, 100 mg/kg) had an antidepressant effect compared with the depression model group	Antidepressant activity through increased protein expression of p-CREB and BDNF	[61]
	PCWPW and PCWPS	In vivo, PCWPW and PCWPS (300 mg/kg) possess antidepressant-like effects	—	[62]

Table 3: Continued.

Type of the activities	Subjects	Activities	Mechanisms	Ref.
Other biological activities	Total triterpenes and poricoic acid A	In vitro, the effects of total triterpenes and poricoic acid A on the inhibition of tyrosinase activity in cells increased with a rising concentration of 12.5 μg/mL	Pharmacological activity through inhibition of monophenolic and diphenolic enzyme activities in tyrosinase	[99]
	Poria ethanol extract	*Poria* ethanol extract (at 100 μg/mL) can reduce the expression of tyrosinase and MITF in B16F10 in vitro, and applying 2% ointment containing *Poria* extract on cheeks in vivo can reduce the skin color value	By regulating tyrosinase activity and MITF expression to reduce the production of melanin	[100]
	Poria chloroform extract	*Poria* chloroform extract (at 2~3 mg/mL) has a strong tyrosinase inhibition effect in vitro	*Poria* chloroform extract can inhibit the activity of tyrosinase in the process of melanin production and effectively regulate the production of melanin, which is suitable for the development of whitening products for treating pigmented skin diseases	[101]
	PA	PA (100 mg/kg) has significant neuroprotective effects on cerebral ischemia/reperfusion injury and neuronal apoptosis in vivo	The mechanism of action may be related to the activation of the PI3K/Akt signaling pathway	[102]
	Total triterpenes in *Poria* cocos peel (TTP)	In vivo, TTP (100 mg/kg) has antiepileptic activity	—	[103]
	Poria aqueous extract, alcohol extract, and *Poria* polysaccharide	In vivo, *Poria* aqueous extract (at 30, 60, 120 mg/kg), *Poria* alcoholic extract (at 25, 50, 100 mg/kg), and *Poria* polysaccharide (at 10, 20, 40 mg/kg) protect against acute liver injury caused by carbon tetrachloride	Protects the liver by enhancing the liver's antioxidant capacity and reducing inflammation	[104]

increased the urine volume in rabbits within 20 and 30 minutes, which was much higher than that of the control groups [86].

3.4. Hepatoprotective Activity. Wu et al. research demonstrated that *Poria* polysaccharides could reduce the inflammatory stress of liver cells and the biological activity of HSP90, which proved that *Poria* polysaccharides had a liver protective effect against acetaminophen-damaged liver cells [87]. Wang et al. found that carboxymethyl pachyman could reduce liver injury of CT26 mice by regulating NF-κB, Nrf2-ARE, and MAPK/P38/JNK pathways [88].

3.5. Effects on Blood Sugar. Sun et al. proved that pachymic acid could stimulate glucose uptake in 3T3-L1 adipocytes by enhancing GLUT4 expression and transport [89]. Not only that, PAC could also reduce blood glucose in diabetic rats [90]. Sun et al. reported for the first time that insoluble polysaccharide could improve and regulate hyperglycemia and hyperlipidemia in ob/ob mice through intestinal flora [91].

3.6. Antioxidant Effects. Wang et al. experiment showed that PCP-M had the scavenging ability of hydroxyl radical and DPPH radical [60]. Zhang et al. experiment showed that carboxymethyl-pachyman could reduce the generation of MDA in liver tissue and serum of mice and increase the activity of SOD in serum and liver, which indicated that carboxymethyl-pachyman had antioxidant activity [92].

3.7. Anti-Inflammatory Effects. A large number of studies have shown that *Poria* has anti-inflammatory activity. Five compounds were isolated from *Poria* by Rak et al. They were poricoic acid A (94), 3-O-acetyl-16α-hydroxydehydrotrametenolic acid (47), polyporenic acid C (53), 3β-hydroxylanosta-7,9(11),24-trien-21-oic acid(39), and trametenolic acid (3). These compounds could downregulate the expression of COX-2 and PGE2 by inhibiting the production of NO and the expression of iNOS in RAW264.7 cells stimulated by LPS; poricoic acid A exerted the highest anti-inhibitory activity and reduced PGE2 levels via downregulation of COX-2 protein expression, indicating that they had anti-inflammatory activities [93]. Qin's study found that PA could inhibit TNF-α induced oxidative stress and inhibit apoptosis of SH-SY5Y cells by inhibiting ERK/Nrf2 pathway [94].

Coriacoic acid A (131), Coriacoic acid B (73), dehydroeburic acid (46), acetyl eburicoic acid (19), and Poricoic acid C (97) could inhibit NO production, among which the

activities of Poricoic acid C were the strongest. Its mechanism was to exert anti-inflammatory activity by down-regulating NF-kappaB to inhibit the expression of iNOS and COX-2. Coriacoic acid A and Coriacoic acid B were isolated for the first time and found to have anti-inflammatory activity for the first time [30]. CMP33 (35) could inhibit the release of NO, IL-1β, IL-6, and TNF-α in RAW264.7 macrophages stimulated by LPS, indicating that PPS had anti-inflammatory activity [51]. Liang et al. found that *Poria* polysaccharide could inhibit the activation of IL-33/ST2 signaling pathway, reduce the activation of UC, inhibit the expression of inflammatory factors, and reduce the infiltration degree of colitis, which indicated that *Poria* polysaccharide had an obvious therapeutic effect on ulcerative colitis [95].

3.8. Effects on the Gut. Studies showed that *Poria* had a protective effect on the intestinal tract. 16α-hydroxytrametenolic acid (6) could improve intestinal barrier function through glucocorticoid receptor-mediated PI3K/Akt/NF-κB pathway, suggesting that 16α-hydroxytrametenolic acid could strengthen the intestinal barrier [96]. Xiao et al. study showed that the alcohol extract of *Poria* could inhibit intestinal contraction in vitro by blocking the M receptor and regulate intestinal peristalsis function, which provided a new theoretical basis for the treatment of diarrhea type IBS [97]. Zou showed that water-soluble polysaccharides could increase the relative content of probiotic bacteria and decrease the relative content of pathogenic bacteria to regulate the change of intestinal flora structure caused by cis-uranium, and water-soluble polysaccharides could also reduce the intestinal damage caused by cis-uranium by regulating the disturbance of metabolic pathways such as lipid metabolism, amino acid metabolism, and purine metabolism [16]. The experimental results of Song et al. showed that *Poria* powder exerted a regulatory effect on intestinal flora by significantly increasing the level of intestinal bifidobacteria in mice [98].

3.9. Antidepressant. *Poria* has antidepressant activity. Zhang et al. study demonstrated that sulfated pachymaran had antidepressant-like effects in rats, which may be mediated by enhancing GluR1 receptor function and upregulating the protein expression of p-CREB and BDNF in the hippocampus [61]. Zhang et al. experiments showed that the resting time of animals treated with 300 mg/kg PCWPW and PCWPS was also significantly shortened ($P < 0.001$), suggesting that PCWPW and PCWPS have antidepressant effects. PCWPs had a good protective effect on H_2O_2-induced cell death in vitro. Its neuroprotective effect could reduce nerve damage in patients with depression [62].

3.10. Other Biological Activities. *Poria* also showed effect on tyrosinase activity [99–101]. In addition, pachymic acid (1) had protective effects against cerebral ischemia-reperfusion injury and neuronal apoptosis [102]; epidermis extract could be a potential treatment for epilepsy [103]. *Poria*'s aqueous extract, alcohol extract, and polysaccharide showed the protective effects on acute liver injury caused by carbon tetrachloride [104].

4. Conclusion and Prospect

In recent years, many researches have been conducted on the extracts of *Poria* and their multiple biological activities. Poricoic acid A (95), for example, not only showed its impact on the tyrosinase activity but also has a diuretic effect. These active compounds have enormous potential to be developed to treat some diseases with multi-targets safely and effectively. In this paper, both the chemical composition and biological activity of *Poria* were discussed in detail to provide abundant theoretical guidance for the further development of *Poria* as a potential medicinal and edible resource.

Conflicts of Interest

The authors declare no conflicts of interest.

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