



Review Article

A comprehensive review of *Prinsepia utilis* Royle used for food, medicine and cosmetics

Xuan-Zhong Wang^{1,3}, Yan-Xi Li^{1,3}, Hai-Yang Liu^{1,2,3} (✉)

¹ State Key Laboratory of Phytochemistry and Natural Medicines, Kunming Institute of Botany, Chinese Academy of Sciences, Kunming 650201, China

² Yunnan Characteristic Plant Extraction Laboratory, Kunming 650106, China

³ University of Chinese Academy of Sciences, Beijing 100049, China

Received: 29 December 2024 / Revised: 22 March 2025 / Accepted: 25 April 2025

Abstract: *Prinsepia utilis* Royle, a plant native to China and the Himalayan region, remains underutilized despite its potential applications in the food, pharmaceutical, and cosmetic industries. This review examines the phytochemical composition and associated biological activities of *P. utilis*, underscoring its value as a multifunctional resource. The plant contains phenolic acids, flavonoids, anthocyanins, terpenoids, and γ-hydroxynitrile glucosides, which demonstrate diverse biological effects, including antioxidant, antibacterial, lipase-inhibitory, anti-benign-prostatic-hyperplasia, and antiosteoporotic activities. These attributes position *P. utilis* as a promising candidate for functional food and cosmetic development. However, existing studies are predominantly limited to *in vitro* models, highlighting the need for *in vivo* validation. Further research is required to elucidate the bioavailability, health impacts, and mechanisms of its bioactive compounds, alongside optimizing extraction methods and formulating stable industrial applications.

Citation: Wang X. Z., Li Y. X., Liu H. Y. A comprehensive review of *Prinsepia utilis* Royle used for food, medicine and cosmetics. *Food & Medicine Homology*, 2026, 3: 9420137. <https://doi.org/10.26599/FMH.2026.9420137>

1 Introduction

Prinsepia utilis Royle, a thorny deciduous shrub or small tree with green young branches, belongs to the Rosaceae family. Known as “青刺尖 (Qingcijian)” and “打油果 (Dayouguo)” in Chinese, it is also identified by various ethnic names in China, including “Anas” (Naxi ethnic group), “ChuNuo” (Yi ethnic group), and “QingNa” (Mosuo people). This species is widely distributed across southwestern China (Yunnan, Guizhou, Sichuan, and Tibet) and the Himalayan regions of Pakistan, Nepal, Bhutan, and northern India. Demonstrating exceptional adaptability, *P. utilis* thrives at altitudes of 1,400–3,600 meters in diverse habitats such as mountains, river valleys, sparse forests, shrublands, and limestone-exposed slopes, reaching heights of 2–8 meters^[1]. *P. utilis* not only thrives in natural settings but also grows naturally along mountain roads, field edges, near streams and rivers, and around rural homes, making it a perennial woody oil crop with strong resistance to cold, drought, and stress. It is a clump-forming shrub with a flat, round crown and densely thorny branches, featuring elongated oval leaves and bisexual, white or pale yellow flowers that bloom from November to March. The fruit matures from green to purple-red and finally blue-purple with a powdery bloom from April to July^[2].

In China, *P. utilis* is a multifunctional plant with edible, medicinal, and cosmetic uses (Fig. 1). The tender branches and leaves of *P. utilis* are eaten as vegetables in the central and

northwest Yunnan province. It is more famous for its oils, which have been used as cooking oil and skin care oil in Dali, Lijiang, and Shangri-La. Furthermore, its various parts have been utilized in traditional medicines for detoxification, blood circulation, stasis removal, tonification, and bone healing for a long history^[3], which can be traced back to the medicinal monography “*Materia Medica in South Yunnan*” written by Mao Lan in 1436. In this book, it is recorded that the shoot tips of *P. utilis* (“Qingcijian”) can be prepared as a tea or infused in water, possessing therapeutic effects such as throat clearing, digestive enhancement, and heat reduction. The modern material medical monograph “*Xinhua Bencao Gangyao*” records that its stems and leaves are used to treat boils, toothache, gunshot wounds, fractures, and snakebites, the roots are used for treatment of chronic cough, dyspepsia, and rheumatoid arthritis, and the fruits are applied to address eye diseases and digestive disorders^[4]. A decoction of its roots, stems, leaves, flowers, and fruits can be consumed to reduce inflammation, relieve pain, detoxify, and to act as an antidote in cases of poisoning^[5]. Additionally, the root barks of *P. utilis* are applied to treat stomach ailments in Nepal’s far west. Its shoot tips, leaves, flowers, and fruits, when mashed, can be applied to skin injuries, burns, boils, and insect bites to reduce inflammation, pain, and swelling^[6].

Its multiple uses have attracted the interest of natural products chemists and pharmacologists. Since the 1970s, the diverse chemical components present in *P. utilis* have inspired scientific

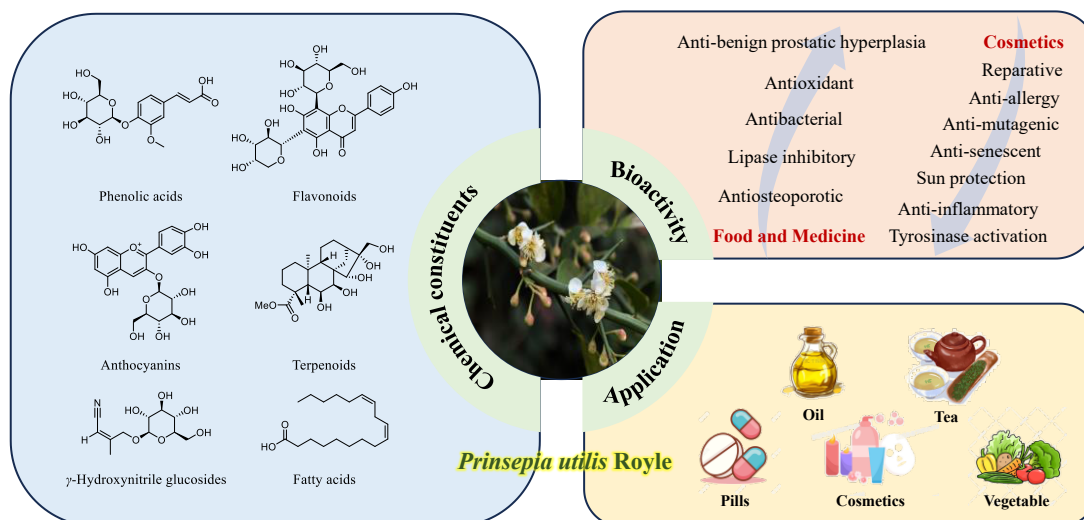


Figure 1 The overview of *Prinsepia utilis* Royle.

research. To date, more than 130 compounds have been published, including phenolic acids, terpenes, anthocyanins, flavonoids, and γ -cyanogenic glycosides, many of which have been found to possess significant biological activities. Although some researchers have published reviews on *P. utilis*, detailing the compounds and structures isolated from various parts of the plant, a comprehensive summary of its medicinal and dietary values is still lacking. This review addresses three critical gaps by updating recent research on the chemical components and biological activities of *P. utilis*: (1) the disconnect between *in vitro* bioactivity and *in vivo* efficacy; (2) the industrial scalability of its lipid-rich seeds as functional food matrices; (3) the medicinal and cosmetic values of the extracts and bioactive components from different parts of this plant.

2 Chemical constituents

Plants produce a multitude of mixed low molecular weight compounds known as “natural products” or secondary metabolites, which often possess flexible metabolic properties necessary for biotic and abiotic responses^[7]. The majority of natural products exert certain biological activities within the human and animal body, thereby preventing or treating diseases. Bioactive components derived from edible plants exhibit non-toxicity or low toxicity, and are beneficial to human health^[8].

Recent literature has indicated that different parts of *P. utilis* contain diverse nutritional and bioactive phytochemicals, including phenolic acids, flavonoids, terpenes, fatty acids, lignans, anthocyanins, tannins, and γ -cyanogenic glycosides. To date, a total of more than 130 compounds has been identified. In this review, 125 representative phytochemicals isolated from *P. utilis* are listed and introduced.

2.1 Phenolic acids and their derivatives

Phenolic compounds in plants are vital to the human diet, offering substantial antioxidant effects and numerous health advantages. Epidemiological evidence suggests that a diet rich in antioxidant vegetables and fruits can significantly reduce the risk of many diseases associated with oxidative stress, such as cancer, diabetes, and cardiovascular diseases^[9]. Phenolic acids are carboxylic acids derived from benzoic or cinnamic acid skeletons^[8]. Until now, a total of 13 phenolic acids has been identified in the different tissues of *P. utilis* (Fig. 2 and Table 1). Protocatechuic acid (1) and *p*-coumaric acid (2) have been extracted and identified from its fruits for the first time^[10]. Then, *p*-hydroxybenzoic acid (4), 3,4-dihydroxybenzoic acid (5), caffeoyl glucose (8), vanillic acid hexoside (9), salicylic acid *O*-hexoside (10), ferulic acid β -glucoside (11), and primeveroside salicylic acid (14) were isolated from its seeds. Meanwhile, Zheng *et al.*

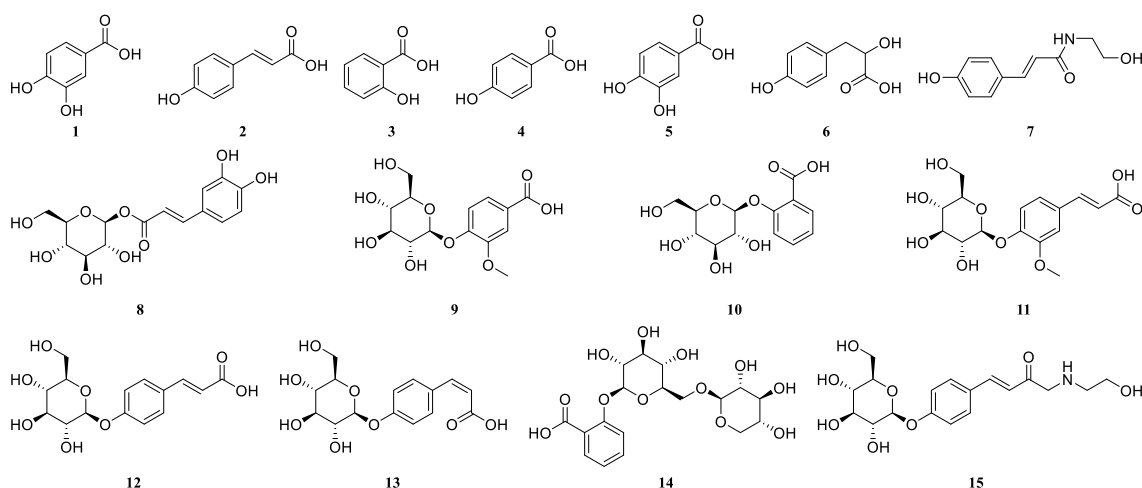


Figure 2 Chemical structures of phenolic acids and their derivatives present in *P. utilis*.

Table 1 Chemical constituents from *P. utilis*

Number	Chemical constituents	Plant part	References
Phenolic acid and their derivatives			
1	Protocatechuic acid	Fruits, seeds, leaves, seed shells	[10, 12, 20, 48, 49]
2	<i>p</i> -Coumaric acid	Fruits, stems	[10, 19, 48]
3	Salicylic acid	Seed shells	[20]
4	<i>p</i> -Hydroxybenzoic acid	Seeds	[43, 50]
5	3,4-Dihydroxyben-zoic acid	Seeds	[43, 51]
6	DL-3-(4-hydroxyphenyl) lactic acid	Seed shells	[11]
7	<i>N</i> -(2-hydroxyethyl)-3-(4-hydroxyphen-yl)-2-propenamide	Oil residues	[44]
8	Caffeoyl glucose	Seeds, leaves	[12, 49]
9	Vanillic acid hexoside	Seeds	[49]
10	Salicylic acid <i>O</i> -hexoside	Seeds, leaves	[12, 49]
11	Ferulic acid β -glucoside	Seeds, leaves	[12, 49]
12	<i>Cis-p</i> -coumaric acid 4- <i>O</i> - β -D-glucopyranoside	Leaves	[12]
13	<i>Trans-p</i> -coumaric acid 4- <i>O</i> - β -D-glucopyranoside	Leaves	[12]
14	Primeveroside salicylic acid	Seeds	[49]
15	Adenosine	Oil residues	[44]
Flavonoids and flavonoid glucosides			
16	(+)-Catechin	Seed shells	[11]
17	(-)-Catechin	Fruits, seed shells, stem	[10, 11, 19]
18	(-)-Epicatechin	Seed shells	[11]
19	(-)-Epigallocatechin	Seed shells	[11, 20]
20	Dihydrokaempferol	Seed shells	[20]
21	Dihydroquercetin	Seed shells	[20]
22	Eriodictyol 7- <i>O</i> -glucoside	Seeds	[49]
23	Dihydroquercetin rhamnoside	Fruits	[10]
24	Sinensin	Oil residues	[44]
25	Quercetin-3-(6- <i>O</i> -acetyl- β -glucoside)	Fruits, stems	[10, 19]
26	Isoschaftoside	Fruits, leaves, stems	[10, 12, 19]
27	Vicenin-2	Leaves	[12]
28	Rutin	Fruits, leaves, seeds, stems	[10-12, 19, 49]
29	Isosakuranetin 7- <i>O</i> -rutinoside	Seeds	[49]
30	Apigenin-7- <i>O</i> -rutinoside	Seeds	[49]
31	Apiin	Seeds	[49]
32	Luteolin	Seed shells	[20]
33	Luteoloside	Seed shells	[20]
34	Luteolin-7- <i>O</i> -rutinoside	Seeds, seed shells, leaves	[11, 12, 49]
35	Quercetin	Seed shells	[11]
36	Quercetin-3- <i>O</i> -glucoside	Fruits, seeds, seed shells, stems	[10, 11, 19, 20, 49]
37	Quercetin-3- <i>O</i> -(2'',6''-di- <i>O</i> - α -L-rhamnopyransoyl)- β -D-glucopyranoside	Leaves	[12]
38	Quercetin-3- <i>O</i> -rutinoside	Leaves	[18]
39	Quercetin 3- <i>O</i> -glucosyl-rutinoside	Leaves	[18]
40	Quercetin-3- <i>O</i> -(2''- <i>O</i> - β -D-xylopyranosyl-6''- <i>O</i> - α -L-rhamnopyranosyl)- β -D-glucopyranoside	Leaves	[12]
41	Quercetin rhamnosyl-glucosyl-rutinoside	Leaves	[18]
42	Isorhamnetin-3- <i>O</i> -glucoside	Fruits, stems	[10, 19, 20]
43	Narcissin	Fruits, leaves, seeds, stems	[10-12, 18, 19, 49]
44	Isorhamnetin-3- <i>O</i> -rutinoside-(1 $\rightarrow$ 2)- <i>O</i> -rhamnoside	Leaves	[18]
45	Isorhamnetin glucosyl-rutinoside	Leaves	[18]
46	Kaempferol-3- <i>O</i> -glucoside	Fruits, seeds, stems	[10, 19, 49]
47	Kaempferol-3- <i>O</i> -rutinoside	Leaves, seeds	[12, 18, 49]
48	Kaempferol-3- <i>O</i> -rutinoside-7- <i>O</i> - β -D-glucopyranoside	Leaves, seeds	[12, 18, 49]
49	Kaempferol-3- <i>O</i> -rutinoside-(1 $\rightarrow$ 2)- <i>O</i> -rhamnoside	Leaves	[18]

(Continued)

Number	Chemical constituents	Plant part	References
50	Kaempferol-3- <i>O</i> -(2'',6''-di- <i>O</i> - α -L-rhamnopyransoyl)-7- <i>O</i> - β -D-glucopyranoside	Leaves	[12]
51	Kaempferol rhamnosyl-glucosyl-rutinoside	Leaves	[18]
52	Procyanidin B1	Seed shells	[20]
53	Procyanidin B2	Seed shells	[11]
Anthocyanins			
54	Cyanidin-3- <i>O</i> -glucoside	Fruits	[10]
55	Cyanidin-3- <i>O</i> -rutinoside		
56	Peonidin-3- <i>O</i> -rutinoside		
57	Delphinidin-3- <i>O</i> -rutinoside		
58	Petunidin-3- <i>O</i> -glucoside		
59	Peonidin-3- <i>O</i> -sophoroside-5- <i>O</i> -glucoside		
Hemiterpenoids			
60	Utililactone	Leaves	[36]
61	Epiutililactone		
Monoterpenoids			
62	Limonene	Leaves	[37]
63	1-8-cineole		
64	<i>O</i> -cymene		
65	<i>Cis</i> -linalooloxide		
66	<i>Cis</i> -sabinene hydrate		
67	Linalool		
68	<i>Trans</i> -terpineol		
69	Isomenthol		
70	α -Terpineol		
Diterpenoids			
71	ent-6 β ,7 β ,15 α ,16 α ,17-Pentahydroxykauranoic acid ether	Oil residue	[44]
72	Prinsoside A	Seeds, oil residue	[38, 44]
73	Prinsoside B	Seeds	[38]
74	Prinsoside C		
Triterpenoids			
75	Cecropiacic acid	Leaves	[36]
76	2 α - <i>O</i> - <i>trans-p</i> -coumaroyl-3 β ,19 α -dihydroxy-urs-12-en-28-oic acid	Aerial parts	[39]
77	2 α - <i>O</i> - <i>cis-p</i> -coumaroyl-3 β ,19 α -dihydroxy-urs-12-en-28-oic acid		
78	3- <i>O</i> - <i>trans-p</i> -coumaroyltormentic acid		
79	3- <i>O</i> - <i>cis-p</i> -coumaroyltormentic acid		
80	3- <i>O</i> - <i>trans-p</i> -coumaroyl-2 α -hydroxyursolic acid		
81	3- <i>O</i> - <i>cis-p</i> -coumaroyl-2 α -hydroxyursolic acid	Aerial parts, leaves	[36, 39]
82	3- <i>O</i> - <i>trans-p</i> -coumaroylmaslinic acid		
83	3- <i>O</i> - <i>cis-p</i> -coumaroylmaslinic acid		
84	Ursolic acid	Leaves	[36]
85	Corosolic acid		
86	Pomolic acid		
87	Tormentic acid	Aerial parts, leaves	[36, 39]
88	Oleanolic acid		
89	Maslinic acid	Leaves	[36]
γ -Hydroxynitrile glucosides			
90	Osmaronin	Seeds, oil residues	[43, 44, 52]
91	Sutherlandin	Oil residues	[44]
92	Prinsepicyanoside A	Seeds, oil residues	[43, 44]
93	Prinsepicyanoside B	Seeds	[43]
94	Prinsepicyanoside C	Seeds, oil residues	[43, 44]

(Continued)

Number	Chemical constituents	Plant part	References
95	Prinsepicyanoside D	Seeds	[43]
96	Prinsepicyanoside E	Seeds	[43]
97	Prinsepicyanoside F		
98	Prinsepicyanoside G		
99	Prinsepicyanoside H	Oil residues	[44]
100	Prinsepicyanoside I		
	Organic acid		
101	Gluconic acid	Seed shells	[11]
102	Quinic acid	Seed, seed shells	[11, 49]
103	Dihydrophaseic acid	Oil residues	[44]
	Fatty acid		
104	Azelaic acid	Seed shells	[11]
105	Palmitic acid	Seeds	[43, 53]
	Tannins		
106	Urolithin C	Seed shells	[11]
	Lignan		
107	Prinsepiol	Stems	[54]
108	Pinoresinol- <i>O</i> - β -D-glucopyranoside	Oil residues	[44]
109	Ambrosidine	Oil residues	[44]
110	Isolariciresinol 9- <i>O</i> -glucoside	Seeds	[49]
	Others		
	Aldehyde		
111	4-Hydroxybenzaldehyde	Seed shell	[20]
112	Bergamal	Leaves	[37]
	Ketones		
113	2-Undecanone	Leaves	[37]
114	Tridecanone	Leaves	[37]
	Alcohols		
115	2-Dodecanol	Leaves	[37]
	Ester		
116	Dimethyl 2-methylsuccinate	Seeds	[43, 55]
117	Monoethyl oxalate	Seeds	[43, 56]
118	4-(hydroxymethyl)-5H-furan-2-one	Seeds	[43, 57]
119	2- <i>O</i> -(3',4'-dihydroxybenzoyl)-4,6-dihydroxyphenylmethyl acetate	Oil seeds	[44]
	Ribonucleoside		
120	Prinamoside A	Oil residues	[44]
	Phenylpropanoids		
121	Benzyl β -D-glucopyranoside	Oil residues	
122	2-Phenylethyl- β -D-glucopyranoside	Oil residues	[44]
123	Triandrin	Oil residues	
	Sterol		
124	β -sitosterol	Seeds	[43, 58]
	Steroid saponin		
125	Dancosterol	Seeds	[43, 59]

investigated the seed shells of *P. utilis*, leading to the isolation of DL-3-(4-hydroxyphenyl) lactic acid (6)^[11]. In addition, Shen *et al.* reported two phenolic acid derivatives, *cis-p*-coumaric acid 4-*O*- β -D-glucopyranoside (12) and *trans-p*-coumaric acid 4-*O*- β -D-glucopyranoside (13), from its leaves^[12].

2.2 Flavonoids and flavonoid glucosides

Flavonoids, a class of low-molecular-weight polyphenolic plant

secondary metabolites, are widely distributed in fruits, vegetables, herbs, beverages, spices, and oils, earning their classification as dietary flavonoids^[13]. These compounds exhibit a broad spectrum of health benefits, including antioxidant, anti-inflammatory, antimutagenic, and anticarcinogenic properties, and modulate key cellular enzymes, contributing to their significance in nutritional supplements, pharmaceuticals, and cosmetics^[14]. Flavonoids, deriving from plants and present in various plant tissues, consist of

(33), luteolin-7-*O*-rutinoside (34), quercetin (35), quercetin-3-*O*-glucoside (36), narcissin (43), procyanidin B1 (52), and procyanidin B2 (53), were putatively identified from the different extracts from *P. utilis* seed shells^[11,20]. According to the structures mentioned, typically occurring as *O*- or *C*-glycosides, flavonoids can also exist as aglycones, with common glycosidic attachments at the C-3 or C-7 positions^[21].

2.3 Anthocyanins

Anthocyanins, flavonoid derivatives synthesized via the phenylpropanoid pathway, serve as natural pigments in plants, flowers, and fruits, and are widely used as food colorants all over the world^[22]. Anthocyanins are sensitive to pH, light, temperature, and molecular structure, affecting their color and stability^[23]. Beyond coloration, they also exhibit significant *in vitro*, animal, and human biological and pharmacological activities, including antioxidant and antimicrobial effects, and the potential to prevent and mitigate non-communicable diseases such as neurodegenerative conditions, cardiovascular diseases, and cancer^[24,25]. The absence of reported adverse effects even at high doses underscores their potential in disease prevention and treatment, highlighting anthocyanins' dual role as both food colorants and health-promoting nutritional components. So far, only six anthocyanidin-type compounds (Fig. 4 and Table 1), cyanidin-3-*O*-glucoside (54), cyanidin-3-*O*-rutinoside (55), peonidin-3-*O*-rutinoside (56), delphinidin-3-*O*-rutinoside (57), petunidin-3-*O*-glucoside (58), and peonidin-3-*O*-sophorose-5-*O*-glucoside (59), were characterized from *P. utilis*. Meanwhile, these six anthocyanins were characterized and quantified in the fruits of *P. utilis*^[10].

2.4 Terpenoids

Terpenoids are a diverse class of hydrocarbons synthesized by plants and found in fruits, vegetables, and flowers^[26]. They function as semiochemicals in the plant kingdom, contributing to plant fragrances^[27]. Terpenoids also have significant applications in

food, serving as flavorings, sweeteners, nutritional fortifiers, and are highly favored as a class of natural additives^[28]. Derived from isoprene (C₅H₈) units^[29], terpenoids are categorized based on the number of isoprene units: hemiterpenes (C₅), monoterpenes (C₁₀), sesquiterpenes (C₁₅), diterpenes (C₂₀), triterpenes (C₃₀), tetraterpenes (C₄₀), and polyterpenes^[30]. As of October 2024, hemiterpenes, monoterpenes, diterpenes, and triterpenes have been isolated from *P. utilis* (Fig. 5 and Table 1). A multitude of terpenoids have been demonstrated to be effective in chemoprevention and chemotherapy, exhibiting antimicrobial, antifungal^[31], antiviral^[32], hypoglycemic^[33], anti-inflammatory^[34], and antimalarial^[35] activities.

Xu and coworkers have first reported two new hemiterpenoids containing chlorine, utililactone (60) and epiutililactone (61), from *P. utilis* leaves^[36]. Simultaneously, 9 triterpenoids, cecropiic acid (75), 3-*O*-*trans*-*p*-coumaroylmaslinic acid (82), 3-*O*-*cis*-*p*-coumaroylmaslinic acid (83), ursolic acid (84), corosolic acid (85), pomolic acid (86), tormentic acid (87), oleanolic acid (88), and maslinic acid (89), were obtained. A gas chromatography-mass spectrometry (GC/MS) analysis of the essential oil from *P. utilis* leaves by steam distillation was carried out, and nine monoterpenoids, namely limonene (62), 1,8-cineole (63), *O*-cymene (64), *cis*-linalooloxide (65), *cis*-sabinene hydrate (66), linalool (67), *trans*-terpineol (68), isomenthol (69), and α -terpineol (70), were detected^[37]. Three polyhydroxylated *ent*-kaurane diterpenoid glycosides, prinsosides A and B (72 and 73) and prinsoside C (74) featuring B-ring cleavage, were isolated from the seeds of *P. utilis*^[38]. The aerial parts of *P. utilis* collected from the Weixi Lisu Autonomous County of the Yunnan province yielded two new triterpenoids, 2 α -*O*-*trans*-*p*-coumaroyl-3 β ,19 α -dihydroxy-urs-12-en-28-oic acid (76) and 2 α -*O*-*cis*-*p*-coumaroyl-3 β ,19 α -dihydroxy-urs-12-en-28-oic acid (77), together with eight known pentacyclic triterpenoids (78–84 and 88)^[39].

2.5 γ -Hydroxynitrile glucosides

Hydroxynitrile glucosides, a class of plant secondary

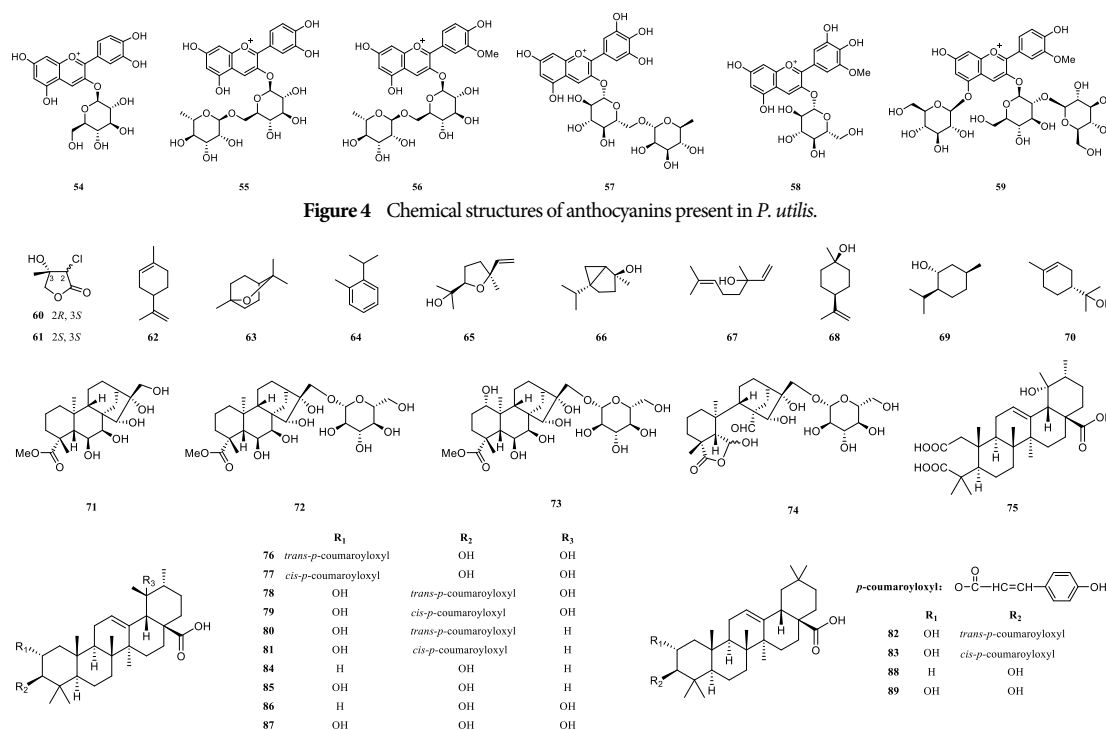


Figure 5 Chemical structures of terpenoids present in *P. utilis*.

metabolites, typically occur as cyanogenic glucosides, namely α -hydroxynitriles. These compounds are widespread throughout the plant kingdom, including ferns, gymnosperms, and angiosperms, and consequently are frequently found in food and fodder sources^[40]. Among plants that produce cyanogenic glucosides, several also synthesize β - and γ -hydroxynitrile glucosides in addition to α -hydroxynitrile glucosides. It is noteworthy that upon hydrolysis, α -hydroxynitrile glucosides yield unstable α -hydroxynitriles that readily release hydrogen cyanide (HCN), which is toxic to respiratory organisms^[41,42]. In contrast, the other two types of cyanogenic glucosides do not exhibit this phenomenon. Unfortunately, the biological functions and significance of β - and γ -hydroxynitrile glucosides remain unclear to date. In 2014, one known osmaronin (**90**) and five new derivatives, prinsepicyanosides A–E (**92–96**), were reported from *P. utilis* seeds^[43]. They may have evolved to be potent antibacterial agents. Subsequently, an investigation on its seed oil residues led to the isolation of eight γ -hydroxynitrile glucosides, including four new ones (**97–100**)^[44]. Their structures and source were presented in Fig. 6 and Table 1. Hydroxynitrile glucosides in the seeds of *P. utilis* may be affected by high temperatures during the oil extraction process and decompose, thus the oil itself does not produce toxicity^[45].

2.6 Fatty acids

Fatty acids, integral lipid constituents, are ubiquitous in the

living cells of plants, animals, and microorganisms. They typically manifest as straight chains with an even number of carbon atoms, featuring hydrogen atoms along the chain and a carboxyl group ($-\text{COOH}$) at one terminus^[46]. Fatty acids are classified based on the saturation of their carbon-carbon bonds into two main categories: saturated and unsaturated. Saturated fatty acids have carbon atoms exclusively linked by single bonds, whereas unsaturated fatty acids contain one or more double or triple bonds, endowing them with higher reactivity. Unsaturated fatty acids serve multiple functions in the body, including the regulation of blood lipids, modulation of immune responses, resolution of thrombi, and maintenance of retinal health^[47].

Gas chromatography analysis of the fatty acid profile of *P. utilis* seed oil (PUSO) revealed a predominant presence of unsaturated fatty acids, constituting approximately 70% of the total fatty acids. Notably, linoleic acid, an essential unsaturated fatty acid with significant hypotensive and lipid-lowering effects on human health, accounts for 37.15% of the total unsaturated fatty acids. As the human is incapable of synthesizing linoleic acid, it must be primarily acquired through dietary sources. This highlights the pivotal role of consuming PUSO in facilitating the absorption of essential fatty acids and in fulfilling the nutritional requirements for a balanced lipid profile^[1]. Additionally, other fatty acids, including azelaic acid (**104**) and palmitic acid (**105**), were also found in PUSO, further contributing to its high nutritional value (Fig. 7 and Table 1).

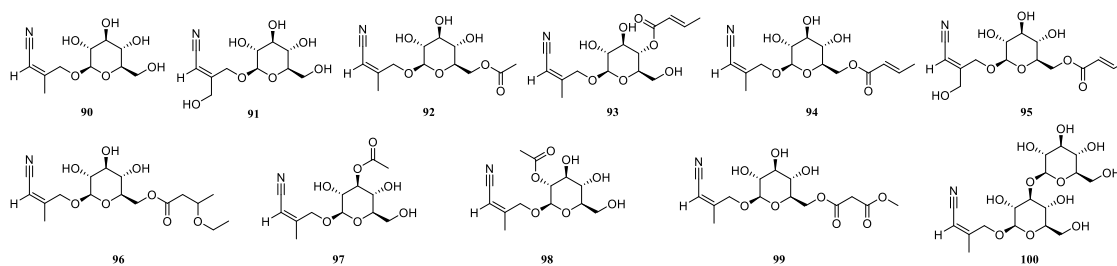


Figure 6 Chemical structures of γ -hydroxynitrile glucosides present in *P. utilis*.

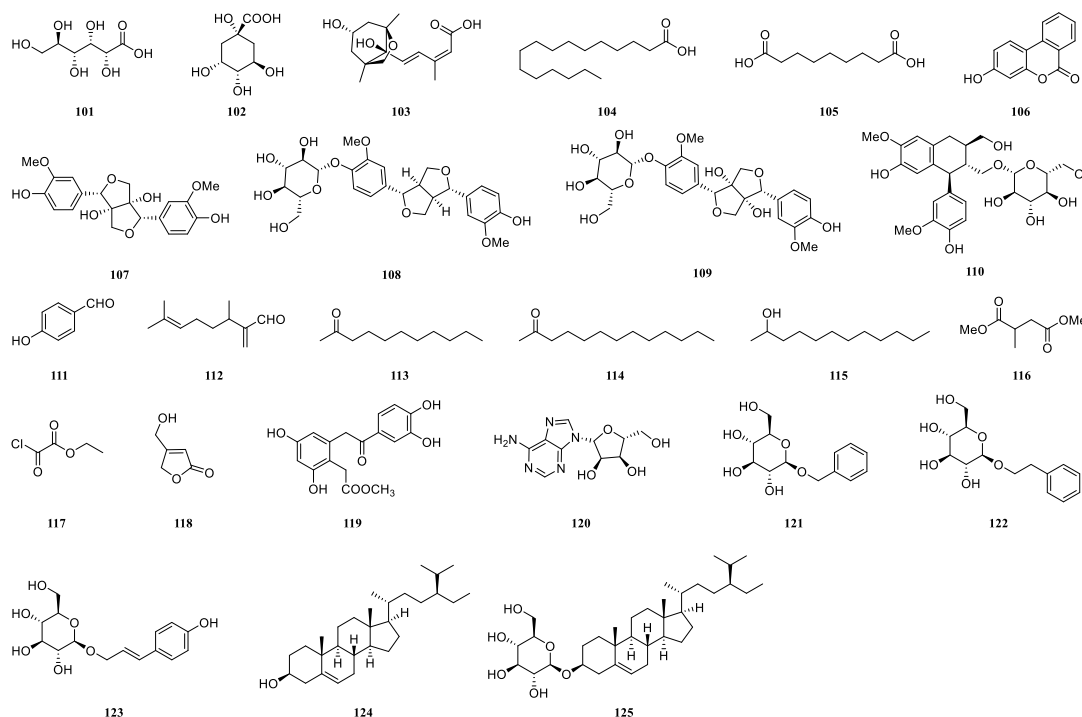


Figure 7 Chemical structures of fatty acid, tannins, lignan and other compounds present in *P. utilis*.

2.7 Other compounds

Apart from the types mentioned above, two organic acids, gluconic acid (**101**) and quinic acid (**102**), were identified from seeds of *P. utilis*, and one dihydrophaseic acid (**103**) was found in oil residues. One tannin, urolithin C (**106**), was reported from the seed shells of *P. utilis*^[11]. Two lignans, pinoresinol-*O*- β -D-glucopyranoside (**108**) and ambrosidine (**109**), were identified from its oil residues^[44]. Prinsepiol (**107**) and isolaricresinol 9-*O*-glucoside (**110**) were reported from its stems and seeds, respectively (Fig. 7 and Table 1). Moreover, two aldehydes (**111** and **112**), two ketones (**113** and **114**), one alcohol (**115**), four esters (**116–119**), one ribonucleoside (**120**), three phenylpropanoids (**121–123**), one sterol (**124**), and one steroid saponin (**125**) have also been reported from *P. utilis* (Fig. 7 and Table 1).

3 Applications in various fields

3.1 Applications in food and drink

3.1.1 Edible oil.

As a woody oil-bearing plant, the seeds of *P. utilis* can be pressed for oil, which has been widely used as cooking oil in Dali, Lijiang, and Shangri-La cities of Yunnan province for a long time. The oil is clear and golden-yellow, with a smooth texture and a pure fragrance, making it an ideal green, healthy edible oil (Fig. 8). Nutritionists have praised it as a “new source of essential fatty acids for humans” and “edible cosmetics”^[60]. Analysis of the fatty acid composition of PUSO, conducted via gas chromatography, revealed a high content of unsaturated fatty acids, 76.6% with monounsaturated fatty acids constituting 38.1% and polyunsaturated fatty acids 38.5%. Meanwhile, the content of saturated fatty acids is 23.4%^[61]. Above all, the ratio of these three fatty acids is notably close to the human body’s optimal fatty acid ratio of 1:1:1, thereby enhancing its bioavailability and metabolic utilization^[62]. While olive oil is predominantly composed of monounsaturated fatty acids (MUFAs), notably oleic acid (77%), and flaxseed oil is rich in polyunsaturated fatty acids (PUFAs) such as α -linolenic acid (ALA), PUSO exhibits a hybrid lipid

profile that integrates the metabolic advantages of both MUFA-mediated oxidative stability and PUFA-derived bioactive properties.

Despite the demonstrated health benefits, consumer adoption is further limited by insufficient awareness of its scientifically validated advantages. To address these challenges, strategic imperatives include: robust validation of health claims, diversification into adjacent markets, and technological innovations to reduce cultivation and processing costs. In addition, PUSO has not yet been approved for market release by the National Health Commission of the People’s Republic of China, which limits the production of PUSO. We hereby strongly urge the government, researchers, and enterprises together to intensify the relevant studies to facilitate the legalization of its application, thereby enabling the oil to realize its full value.

Luo *et al.* systematically compared three PUSO extraction methodologies: supercritical CO₂ (SCFE), ultrasonic-assisted, and cold-pressing techniques. While all methods produced oils with comparable fatty acid profiles (predominantly oleic, linoleic, palmitic, and stearic acids), significant disparities emerged in operational efficiency and product characteristics. Ultrasonic extraction achieved maximal yield (32.5%), surpassing SCFE (31.9%), and cold-pressing (28.2%). Analytical characterization revealed SCFE-derived oil exhibited optimal organoleptic properties, presenting as a solvent-free pale golden liquid with refined aroma and favorable viscosity. Contrastingly, ultrasonic-extracted oil demonstrated opalescent coloration and detectable petroleum ether residues, while cold-pressed oil contained lipid-soluble impurities and elevated viscosity. Nutritional profiling showed SCFE oil most closely approximated ideal dietary fatty acid ratios despite ultrasonic methods yielding marginally higher unsaturated fatty acid content (65.8% vs 65.2%). This study established SCFE as the superior technique for premium oil production, balancing nutritional integrity with sensory quality, whereas ultrasonic methods required solvent residue mitigation despite their yield advantage. Cold-pressing demonstrated limitations in both efficiency and purity parameters^[63].

3.1.2 Vegetables and tea drinks.

The shoot tips of *P. utilis* have been traditionally used as vegetables and tea in the central and northwest Yunnan province, which has shown potential benefits in managing benign prostatic hyperplasia (BPH) symptoms (Fig. 8). Based on this background^[18], the aqueous extract of *P. utilis* leaves was evaluated for its potential in alleviating symptoms of benign prostatic hyperplasia (BPH) using animal models in 2019. As a result, the Fr.B separated from this extract was confirmed as the active fraction^[64]. A continuous investigation was observed that Fr.B significantly decreased the levels of vascular endothelial growth factor (VEGF) and malondialdehyde (MDA) in prostate tissue after a 28-day administration, while concurrently increasing the levels of superoxide dismutase (SOD), glutathione peroxidase (GSH-Px), and catalase (CAT), all of which are critical antioxidants in the body. Furthermore, this fraction significantly reduced the levels of dihydrotestosterone (DHT) and the DHT/estradiol (E2) ratio, key markers in BPH pathology, and decreased tumor necrosis factor- α (TNF- α), a pro-inflammatory cytokine, while increasing testosterone levels in the serum of BPH rats. Furthermore, ten flavonoid glycosides were assigned from the active fraction by UPLC-Q-TOF-MS and quantified by HPLC. These findings underscored the multifaceted anti-BPH mechanisms of the active fraction, including modulating the hormonal balance of DHT/E2, inhibiting inflammatory responses, and enhancing antioxidant defenses^[18]. Based on this



Figure 8 Application of *P. utilis* leaves and seeds.

research, functional food products can be developed through processing *P. utilis* leaves into tea for direct consumption, or by incorporating the effective part Fr. B into food formulations. Nevertheless, the transition of *P. utilis* from traditional usage to functional food demands interdisciplinary collaboration among ethnopharmacologists, food scientists, and regulatory experts. Prioritizing functional trials, safety assessment, and sustainable production will bridge the gap between promising preclinical data and commercially viable, health-promoting products. Without addressing these challenges, *P. utilis* remains a niche ingredient rather than a mainstream functional food solution for BPH management.

3.1.3 Fruit preservation function.

The ethanol extract of *P. utilis* has a preservative effect on peaches, with the most significant effect observed when applied as a coating, which slows down the changes in vitamin C, acidity, sugar content, and weight loss, while maintaining the color, texture, and other visual aspects of the fruits^[65].

3.2 Applications in medicines

3.2.1 Antioxidant activity.

Antioxidants contribute to human health due to their ability to donate an electron or hydrogen atom to combat free radicals. Consequently, the *in vitro* assessment of antioxidant capacity is a prevalent method for evaluating the health benefits of food materials. At present, common methods such as 2,2-diphenyl-1-picrylhydrazyl (DPPH), 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS), and intracellular ROS inhibition assays have been employed to evaluate the antioxidant activity of different parts of *P. utilis*. The results suggested that its fruits, leaves, seeds, and stems exhibit significant antioxidant activity (Table 2).

Liu *et al.* evaluated the antioxidant activities of the fruits during digestion through DPPH and ABTS radical cation scavenging assays and found that the undigested sample (CG), gastric digested sample (GD), and intestinal digested sample (ID) exhibited good DPPH radical scavenging activities in a dose-dependent response^[10]. The IC₅₀ values of the DPPH radical scavenging abilities of CG, GD, and ID were determined to be 35.9 ± 2.06, 32.3 ± 1.81, and 20.1 ± 1.32 µg/mL, respectively. Meanwhile, the IC₅₀ values of the ABTS radical scavenging abilities of CG, GD, and ID were 58.4 ± 1.33, 38.6 ± 1.29, and 27.9 ± 2.42 µg/mL, respectively. These findings indicated an enhancement in the DPPH radical cation scavenging ability following simulated digestion, which suggested an increase in ABTS radical scavenging activity post-digestion in comparison to the undigested state. Another study explored the antioxidant potential of phenolic compounds extracted from the seeds, both in their natural state and following fermentation, while subjected to a simulated *in vitro* model of gastrointestinal digestion^[49]. The antioxidant activities of both native and fermented seeds of *P. utilis* were also evaluated throughout the digestive process using DPPH and ABTS radical scavenging assays. It was observed that fungal fermentation notably enhanced the phenolic content and antioxidant activity of the seeds. These findings provide a better understanding of how fermented foods possess enhanced bioactivity compared to their non-fermented counterparts. Furthermore, the antioxidant activity of free, esterified, and insoluble-bound phenolic fractions of *P. utilis* seed shells was also evaluated using DPPH and ABTS free radical scavenging assays. The IC₅₀ values of free phenolic,

esterified phenolic, and insoluble-bound phenolic extracts for DPPH were 6.91 ± 0.20 µg/mL, 4.89 ± 0.19 µg/mL, and 9.02 ± 0.32 µg/mL, respectively, and 2.14 ± 0.27 µg/mL, 2.28 ± 0.19 µg/mL, and 3.11 ± 0.19 µg/mL, respectively, for ABTS. Obviously, the esterified phenolics had the strongest scavenging effect^[66]. Zheng and collaborators found the higher antioxidant capacity of the ethanol extract of *P. utilis* flowers compared to the extract of its leaves and stems using DPPH, ABTS, and FRAP assays. These findings could potentially support the development and utilization of *P. utilis* in food and health products^[19]. Although discrepancies in the bioactive data exist in the literatures, the antioxidant activity of different parts of this plant has been demonstrated.

3.2.2 Antibacterial activity.

A study on the extracts of *P. utilis* seeds with different solvents (hexane, ethyl acetate, and methanol) showed promising results regarding their antibacterial activity^[67] (Table 2). Utilizing the disc diffusion method, the ethyl acetate leaves extract demonstrated the strongest antibacterial activity against *Staphylococcus epidermidis* with a zone of inhibition (ZOI) measuring 13.83 mm. Furthermore, the MIC and MBC values of this extract against *S. epidermidis* were 0.5 mg/mL and 0.6 mg/mL, respectively. However, the hexane leaf extract exhibited weaker anti-*S. epidermidis* activity with MIC and MBC values of 20.8 mg/mL and 33.3 mg/mL, respectively. Similarly, the methanolic leaves' extract exhibited the highest efficacy against *S. aureus* with a ZOI of 12.33 mm. Additionally, the methanolic seed extract displayed the greatest sensitivity towards *Klebsiella pneumoniae* (ZOI = 11.66 mm) and *Escherichia coli* (ZOI = 9.0 mm). Pu *et al.* reported that the ethyl acetate extract of its seeds yielded seven fractions by silica gel column chromatography, with the first and fourth fractions showing the most potent antibacterial activity against *S. aureus* ATCC25923, *Escherichia coli* ATCC44102, and *Salmonella* sp. CMCC(B)50041 at a concentration of 20 mg/mL^[68]. Specifically, the mean diameters of the inhibition zones for the two fractions against *S. aureus* ATCC25923 were 14.16 mm and 15.26 mm, respectively, which were larger than the 13.76 mm observed for oregano oil at the same concentration. Additionally, these fractions displayed equivalent inhibitory effects to oregano oil against *E. coli* ATCC44102 and *Salmonella* CMCC(B)50041. Additionally, two γ-hydroxynitrile, osmaronin (90) and prinsepicyanoside A (92), along with 4-(hydroxylmethyl)-5H-furan-2-one (118) showed certain antibacterial activities against *Salmonella gallinarum*, *Vibrio parahaemolyticus*, and *Vibrio cholerae* with respective MICs of 30.1 µg/mL, 20.7 µg/mL, and 22.8 µg/mL^[43]. Ciprofloxacin was used as a positive control drug, with MIC values of 0.41, 0.2, and 0.8 µg/mL, respectively. Next studies should evaluate the antimicrobial spectrum and potential of the combination with different antibiotics of *P. utilis*.

3.2.3 Lipase and α-glucosidase inhibitory activity.

Dietary lipids require hydrolysis by pancreatic lipase before absorption, and the inhibition of this enzyme is considered an effective strategy for managing obesity^[69]. Numerous studies have demonstrated that plant-based extracts rich in phenolic compounds exhibit potent inhibitory activity against lipase^[70]. The ethanol extracts of *P. utilis* flowers, leaves, and stems showed significant pancreatic lipase inhibitory activities with IC₅₀ values of 1.72 ± 0.03, 1.82 ± 0.15, and 2.56 ± 0.02 mg/mL, respectively (Table 2). Among them, the flower extract with the highest polyphenol content had the highest inhibitory activity, followed by the leaves' and stems' extracts^[19]. Furthermore, the total phenolic

Table 2 Biological activities of *P. utilis*

No.	Biological activity	Medicinal parts	Compounds/extracts	Model	IC ₅₀ /EC ₅₀ /Inhibitory rate	Reference
1	Anti-benign prostatic hyperplasia activity	Leaves	Water extract and active Fr. B from water extract	BPH rats (<i>in vivo</i>)	Water extract and Fr. B alleviated BPH in animal models by modulating the DHT/E2 hormonal balance, enhancing antioxidant defenses, suppressing pro-inflammatory TNF- α , and increasing serum testosterone. IC ₅₀ values of CG, GD, and ID: 35.9 $\pm$ 2.06, 32.3 $\pm$ 1.81, and 20.1 $\pm$ 1.32 μ g/mL, respectively (DPPH); 58.4 $\pm$ 1.33, 38.6 $\pm$ 1.29, and 27.9 $\pm$ 2.42 μ g/mL, respectively (ABTS).	[18]
		Fruits	TPC, TFC, and TAC	DPPH and ABTS (<i>in vitro</i>)	The IC ₅₀ values of TPF, FF, and AF: 4.72 $\pm$ 0.31, 2.46 $\pm$ 0.11, and 4.20 $\pm$ 0.14 μ g/mL, respectively (DPPH); 3.45 $\pm$ 0.48, 3.2 $\pm$ 0.26, and 2.93 $\pm$ 0.35 μ g/mL, respectively (ABTS).	[10]
		Fruits	TPF, FF and AF	Inhibition on cellular reactive oxygen species (ROS) generation in H ₂ O ₂ -induced HepG2 cells models, DPPH and ABTS (<i>in vitro</i>)	The IC ₅₀ values of DPPH radical scavenging activity of native, <i>A. oryzae</i> var. <i>effuses</i> , <i>R. oryzae</i> , and <i>R. oligosporus</i> fermented seeds: 15.36 $\pm$ 0.25, 12.81 $\pm$ 0.63, 10.83 $\pm$ 0.42, and 11.05 $\pm$ 0.27 mg/mL, respectively (DPPH). IC ₅₀ = 62.46 μ g/mL	[48]
2	Antioxidant activity	Native and fermented seeds	Dry seeds	DPPH and ABTS (<i>in vitro</i>)	IC ₅₀ = 4.89 $\pm$ 0.19 μ g/mL (DPPH); 2.28 $\pm$ 0.19 μ g/mL (ABTS)	[49]
		Leaves	Methanolic extract	DPPH (<i>in vitro</i>)	The IC ₅₀ values of the ethanol extracts of <i>P. utilis</i> flowers, leaves, and stems: 46.07 $\pm$ 2.42, 82.08 $\pm$ 0.97, and 71.46 $\pm$ 2.85 μ g/mL, respectively (DPPH); 22.07 $\pm$ 0.94, 27.14 $\pm$ 0.28, and 20.29 $\pm$ 0.57 μ g/mL, respectively (ABTS).	[73]
		Seed shells	The esterified phenolic extract	DPPH and ABTS (<i>in vitro</i>)	The FRAP values of flower, leaf, and stem extracts: 0.60 $\pm$ 0.01, 0.25 $\pm$ 0.003, and 0.19 $\pm$ 0.01 mmol/L, respectively. The leaves ethyl acetate extract: ZOI=13.83 mm; MIC=0.5 mg/mL; MBC=0.6 mg/mL (<i>Staphylococcus epidermidis</i>);	[11]
		Leaves, stems and flowers	Ethanol extracts	DPPH, ABTS and FRAP (<i>in vitro</i>)	The leaves hexane extract: ZOI=12.33 mm; MIC=20.8 mg/mL; MBC=33.3 mg/mL (<i>Staphylococcus epidermidis</i>)	[19]
3	Antibacterial activity	Leaves and seeds	Hexane, ethyl acetate, methanol, and distilled water were used as extraction solvents	The disc diffusion method, MBC and MIC assays (<i>in vitro</i>)	The seeds methanolic extract: ZOI=12.33 mm (<i>S. aureus</i>), 11.66 mm (<i>Klebsiella pneumoniae</i>), 9.0 mm (<i>Escherichia coli</i>).	[67]
		Seeds	Ethyl acetate extract	The disc diffusion method, MBC and MIC assays (<i>in vitro</i>), three bacterial strains (<i>Staphylococcus aureus</i> ATCC25923, <i>Escherichia coli</i> ATCC44102 and <i>Salmonella sp.</i> CMCC(B)50041)	Fr.1: ZOI=14.16 mm, MIC=0.625 mg/mL, MBC=2.5 mg/mL (<i>S. aureus</i> ATCC25923) Fr.4: ZOI=15.26 mm, MIC=0.625 mg/mL, MBC=1.25 mg/mL (<i>S. aureus</i> ATCC25923)	[68]
		Seeds	Osmaronin (90), prinsepicyanoside A (92), and 4-(hydroxylmethyl)-5H-furan-2-one (118)	The disc diffusion method, MBC and MIC assays (<i>in vitro</i>), three bacterial strains (<i>Salmonella gallinarum</i> , <i>Vibrio parahaemolyticus</i> , and <i>Vibrio cholerae</i>)	MIC=30.1 μ g/mL (90 against <i>Salmonella gallinarum</i>), MIC=20.7 μ g/mL (92 against <i>Vibrio parahaemolyticus</i>), MIC=22.8 μ g/mL (118 against <i>Vibrio cholerae</i>)	[43]
		Fruits	TPC, TFC, and TAC		ID possessed the strongest inhibitory activity at 2.4 mg/mL, inhibition rate=80.0%. IC ₅₀ =423.15 $\pm$ 11.12 μ g/mL (TPF), IC ₅₀ =439.98 $\pm$ 25.08 μ g/mL (FF), IC ₅₀ =407.43 $\pm$ 33.89 μ g/mL (AF)	[10]
4	Lipase inhibitory activity	Fruits	TPF, FF and AF	Inhibition of pancreatic lipase assay (<i>in vitro</i>)	IC ₅₀ =1.72 $\pm$ 0.03 (flowers), IC ₅₀ =1.82 $\pm$ 0.15 (leaves), IC ₅₀ =2.56 $\pm$ 0.02 mg/mL (stems)	[48]
		Leaves, stems and flowers	Ethanol extracts		The leaves have effect against induced osteoporosis and improved bone quality, attenuated bone resorption, enhanced the rate of bone formation and restored bone density.	[19]
5	Antiosteoporotic activity	Leaves	Methanolic extracts	Osteoporosis induced by ovariectomy in rats (<i>in vivo</i>)		[73]

(Continued)

No.	Biological activity	Medicinal parts	Compounds/extracts	Model	IC ₅₀ /EC ₅₀ /Inhibitory rate	Reference
6	α -Glucosidase inhibitory activity	Fruits	Protocatechuic acid (1) and <i>p</i> -coumaric acid (2)	Inhibition of α -Glucosidase assay (<i>in vitro</i>)	IC ₅₀ =317 $\pm$ 17.9 μ g/mL (1) IC ₅₀ =10.7 $\pm$ 0.510 μ g/mL (2)	[10]
		Oil residue	Osmaronin (90), prinsepicyanosides C (94) and H (99), Ursolic acid (84), corosolic acid (85), pomolic acid (86), oleanolic acid (88) and maslinic acid (89)		Inhibition rates ranging from 11.92% to 15.70% at the concentration of 500 μ M.	[44]
7	Immunosuppressive effect	Leaves		Lymphocyte transformation test (<i>in vitro</i>)	Inhibition ration=51.03% (84), 48.50% (85), 38.93% (86), 55.98% (88), 44.50% (89) at 20 μ g/mL	[36]
8	Anti-allergy activity and anti-inflammatory activity	Leaves	Water extract	Hyaluronidase inhibitory assay (<i>In vitro</i>) and fluorescein isothiocyanate (FITC)-induced ACD mouse model (<i>in vivo</i>)	IC ₅₀ =231.93 $\pm$ 23.85 μ g/mL	[12]
9	Tyrosinase activation activity	Seed shells	(+)-Catechin (16) and (–)-epicatechin (18)	Tyrosinase activity assay (<i>in vitro</i>), molecular docking and molecular dynamics	EC ₅₀ =32.50 $\pm$ 1.70 μ M (16) EC ₅₀ =36.71 $\pm$ 0.43 μ M (18)	[20]
10	Reparative effect	Oil cakes	Water extracts	Tape-stripping (TS) and acetone wiping (AC) methods were used to induce mouse models (<i>in vivo</i>)	The reparative effects were attributed to the upregulation of key proteins, including skin barrier components, lipid synthesis enzymes, and junctional proteins, which collectively enhance epidermal integrity and barrier function.	[4]
11	Anti-mutagenic activity	Oil residue	Hexane extract	Recovery activity assay of damaged DNA (<i>in vitro</i>)	The recovery rate increased from 53.09% at 10 μ g/ μ L to 63.05% at 20 μ g/ μ L.	[82]
12	Anti-senescent activity	Oil residue	Water extract	Anti-hyaluronidase and anti-tyrosinase assays at different concentrations (<i>in vitro</i>)	IC ₅₀ = 0.90 $\pm$ 0.03 mg/mL (hyaluronidase activity), IC ₅₀ = 1.81 $\pm$ 0.02 mg/mL (tyrosinase activity)	[82]
		Seed residue	Flavonoids	D-galactose-induced mouse aging model, Human Foreskin Fibroblast (HFF) model, and 3D full T-Skin™ model (<i>in vivo</i>)	Flavonoids regulated the AMPK/mTOR/TGF- β pathway, exerting dual antioxidant and anti-senescent effects.	[85]
13	Sun protection assay	Oil residue	Water extract	UV spectrophotometric method (<i>in vitro</i>)	Sun protection factor of 11.00 $\pm$ 0.03 at a concentration of 1,000 μ g/mL.	[82]

CG: undigested sample; GD: gastric digested sample; ID: intestinal digested sample; TPC: total phenolic content; TFC: total flavonoid content; TAC: total anthocyanin content.

fraction (TPF), flavonoid fraction (FF), and anthocyanin fraction (AF) from *P. utilis* fruits were evaluated for their lipase inhibitory activity. The IC₅₀ values of TPF, FF, and AF were determined as 423.15 $\pm$ 11.12 μ g/mL, 439.98 $\pm$ 25.08 μ g/mL, and 407.43 $\pm$ 33.89 μ g/mL, respectively. Notably, the positive control drug orlistat exhibited a stronger inhibitory effect (IC₅₀ = 317.90 $\pm$ 2.37 μ g/mL) compared to all phenolic fractions. UHPLC-ESI-HRMS/MS analysis identified rutin, isorhamnetin-3-O-glucoside, and cyanidin-3-O-glucoside as the predominant bioactive constituents in these fractions. Subsequent evaluation revealed distinct inhibitory potencies, with rutin demonstrating the most potent lipase inhibition activity (IC₅₀ = 176.18 $\pm$ 5.11 μ g/mL), followed by isorhamnetin-3-O-rutinoside (237.87 $\pm$ 8.20 μ g/mL) and cyanidin-3-O-glucoside (249.20 $\pm$ 3.87 μ g/mL)^[48]. Although substantial evidence supports the anti-obesity potential of *P. utilis*, its clinical translation remains challenging due to insufficient experimental data to establish robust pharmacological validation.

In addition, Liu *et al.* disclosed the α -glucosidase inhibitory activity of protocatechuic acid (1) and *p*-coumaric acid (2) isolated from the fruits with the IC₅₀ values of 317 $\pm$ 17.9 and 10.7 $\pm$ 0.510 μ g/mL, respectively^[10]. Besides these two phenols, three γ -hydroxynitrile glucosides, osmaronin (90), prinsepicyanoside C (94), and prinsepicyanoside H (99), displayed weak α -glucosidase inhibitory activity, with inhibition rates ranging from 11.92% to 15.70% at the concentration of 500 μ M^[44].

3.2.4 Antiosteoporotic activity.

The leaves and seed oils of *P. utilis* have been traditionally employed for the treatment of rheumatic pain, arthritis, analgesic purposes, bone disorders, and joint ailments^[71,72]. Thus, the leaves' extract administered at dosages of 50, 100, and 200 mg/kg was investigated for its potential effects on ovariectomy-induced osteoporosis in a mouse model. It was found that the extract significantly increased bone density, strength, alkaline phosphatase activity, serum calcium, and serum phosphorus levels. Concurrently, there was a notable decrease in urine hydroxyproline levels relative to the ovariectomized control group^[73] (Table 2).

3.2.5 Immunosuppressive activity.

The *in vitro* immunosuppressive effect of five triterpenoids isolated from *P. utilis* leaves, ursolic acid (84), corosolic acid (85), pomolic acid (86), oleanolic acid (88), and maslinic acid (89), was reported. The results showed that in the studies, these five compounds exhibited a strong immunosuppressive effect with the inhibition ratio of 51.03%, 48.50%, 38.93%, 55.98%, 44.50% at 20 μ g/mL, whereas dexamethasone was used as a positive control, had an inhibition ratio of 41.62% at 50 μ g/mL^[36] (Table 2).

3.2.6 Systems pharmacology of antioxidant and anti-inflammatory synergy.

In diabetic model mice, hepatic degeneration, necrosis, and

interstitial fibroblast hyperplasia were observed. Treatment with *P. utilis* polysaccharides notably attenuated these pathological features. These effects were mechanistically linked to the compounds' multifaceted antioxidant activity, which suppressed inflammatory cascades^[74]. Primarily, they scavenge free radicals and inhibit hyperglycemia-driven overproduction of reactive oxygen species (ROS), thereby reducing lipid peroxidation and oxidative stress. Concurrently, these polysaccharides impair ROS-mediated activation of the p38 mitogen-activated protein kinase (MAPK) signaling pathway, suppressing downstream release of pro-inflammatory cytokines (e.g., TNF- α , IL-1 β , IL-6) and inflammatory cell infiltration. Furthermore, by modulating blood glucose levels, they diminish advanced glycation end product (AGE) accumulation, mitigating AGE receptor (RAGE)-induced oxidative stress and vascular endothelial dysfunction. Additionally, they enhance endogenous antioxidant enzymes such as superoxide dismutase (SOD) and glutathione peroxidase (GSH-Px), bolstering systemic free radical neutralization. Collectively, these synergistic mechanisms reduce inflammatory pathologies in diabetic murine pulmonary tissues, though precise molecular pathways require further experimental validation.

3.3 Applications in cosmetics

In folk traditions, PUSO is commonly used to treat burns, promoting wound healing and preventing scarring. Mosuo women use the oil as a necessity for skincare and hair care, applying it to their hands, face, and hair to prevent sun damage, dryness, and brittleness. Locals in Lijiang City of Yunnan Province prefer it as baby oil, which helps with the shedding of fetal hair and protects the delicate skin of infants, providing hydration and sun protection. In the cosmetic industry, it can serve as a high-quality natural base material for skincare products such as masks and creams, showing excellent effects on beauty, skincare, scars, and pigmentation reduction. In the Jumla region of Nepal, the oil cakes are used to treat eczema or ringworm and for washing clothes. The seed oil is also considered a suitable source for hydrogenation and soap-making agents^[67]. The PUSO exhibits high skin affinity and permeability by structurally and molecularly mirroring natural moisturizing factors (NMF) in the stratum corneum, enabling efficient delivery of hydration and nutrients through enhanced penetration that occurs as its NMF-similar components bind free water to form a networked layer of secondary associated water. This restructure reduces trans-epidermal water loss (TEWL), reinforces the skin barrier, and improves hydration efficacy by stabilizing the stratum corneum matrix. The mechanism supports skin repair and texture refinement through sustained moisture retention^[75]. Comparative analysis with argan oil^[76] has demonstrated that PUSO exhibited significantly higher concentrations of oleic and linoleic acids, closely approximating the composition of human sebum while offering superior epidermal permeability properties.

3.3.1 Anti-allergy activity and anti-inflammatory activity.

P. utilis is recognized for its polyphenol-rich content, which holds potential for anti-inflammatory and skin-protective properties. Allergic contact dermatitis (ACD), a common T-cell-mediated skin inflammation, manifests as localized skin rashes accompanied by itching, redness, and swelling^[77]. The breakdown of hyaluronic acid can result in a loss of skin moisture, decreased resistance to external irritants, and an increased propensity for the skin to develop ACD symptoms^[78]. To evaluate the antiallergic

effects of the water extract from *P. utilis* leaves (PUL), both *in vitro* hyaluronidase inhibitory assays and *in vivo* fluorescein isothiocyanate (FITC)-induced ACD mouse models were conducted. In the *in vitro* studies, the extract exhibited a strong inhibition effect with an IC₅₀ value of 231.93 ± 23.85 μ g/mL, while disodium cromoglycate, used as a positive control drug, had an IC₅₀ value of 545.67 ± 25.12 μ g/mL. Meanwhile, oral administration of the extract demonstrated a dose-dependent reduction in ACD-like symptoms. These findings suggest that the PUL water extract may offer a promising therapeutic strategy for managing ACD by modulating immune responses and strengthening the skin's defensive barriers^[12] (Table 2).

3.3.2 Tyrosinase activation activity.

Tyrosinase, a copper-containing enzyme, is pivotal in the biosynthesis of melanin, a pigment crucial for skin coloration and protection against ultraviolet radiation^[79]. Consequently, maintaining the balance of tyrosinase activity is essential for a healthy skin life and for preventing dermatological disorders associated with abnormal pigmentation^[80]. The tyrosinase activation activities and mechanism of different extracts from *P. utilis* seed shells were evaluated through *in vitro* tyrosinase activity assay, molecular docking, and molecular dynamics simulation studies. As a result, it was observed that both esterified and insoluble bound polyphenols demonstrated the ability to activate tyrosinase^[20]. Notably, the esterified polyphenols exhibited superior tyrosinase-activating properties compared to their insoluble counterparts. Further, two compounds (+)-catechin (**16**) and (–)-epicatechin (**18**) purified from the esterified polyphenols showed significant activation effects on tyrosinase with EC₅₀ values of 32.50 ± 1.70 μ M and 36.71 ± 0.43 μ M, respectively. Employing molecular docking and molecular dynamics simulation studies, it has been elucidated that both phenols could bind efficiently and stably to the active site of tyrosinase through a combination of hydrogen bonds, van der Waals forces, and π -bonds. This stable interaction suggested that these polyphenolic compounds are promising candidates for the modulation of tyrosinase activity (Table 2).

3.3.3 Reparative effect.

Tu *et al.* has demonstrated that PUSO improved cutaneous hydration and barrier function by modulating ceramide (Cer) biosynthesis and upregulating acid ceramidase (ASH1) expression^[81]. *In vitro* experiments using human keratinocytes, treatment with PUSO increased Cer levels by approximately 80% at 24 and 48 hours compared to the control (1.38 ± 0.10 vs. 0.76 ± 0.14 at 24 h; $P < 0.05$). In mice model, topical application of the oil reduced trans-epidermal water loss (TEWL) by 36.7% (8.01 ± 0.58 vs. 12.65 ± 0.71 at day 7), enhanced epidermal hydration by 35.1% (15.86 ± 0.18 vs. 11.74 ± 0.62), and elevated sebum content by 15.8% (31.30 ± 0.88 vs. 27.02 ± 0.65) in treated areas, demonstrating superior efficacy to vehicle and untreated controls ($P < 0.05$). Immunohistochemical analysis revealed time-dependent ASH1 upregulation, peaking on day 7 in oil-treated skin compared to controls. These findings established that PUSO facilitated cutaneous barrier restoration through dual mechanisms: enhancement of Cer synthesis and ASH1-mediated lipid metabolic regulation, providing a molecular basis for its dermatotherapeutic applications.

Recently, the skin reparative effect of the water extracts of *P. utilis* oil cakes (WEPUOC) was reported. In this study, tape-stripping (TS) and acetone wiping (AC) methods were employed to induce epidermal disruptions in mouse models. It was found

that WEPUOC strongly promoted the restoration of compromised epidermal barriers, as indicated by the upregulated expression of proteins essential for barrier integrity. Molecularly, these reparative effects were attributed to the upregulation of key proteins, including filaggrin (FLG), involucrin (INV), loricrin (LOR), sphingomyelin synthase (SPT), fatty acid synthase (FASN), 3-hydroxy-3-methylglutaryl-CoA reductase (HMGCR), and the tight junction proteins claudin-1 and claudin-5, as well as the adherens junction protein ZO-1. However, the active ingredients in WEPUOC remain a mystery (Table 2)^[4].

3.3.4 Anti-mutagenic, sun protection, and anti-senescent activities.

The leftover oil residue extract of *P. utilis* has been reported to possess anti-mutagenic, anti-ageing, and sun protection activity^[82], thereby corroborating the traditional applications of the plant (Table 2). A dose-dependent effect in DNA repair was observed, with the recovery rate increasing from 53.09% at 10 µg/µL to 63.05% at 20 µg/µL, indicating an anti-mutagenic effect of the hexane extract. Additionally, the anti-senescent activity of the water extract was demonstrated through anti-hyaluronidase and anti-tyrosinase assays conducted at different concentrations. IC₅₀ values for hyaluronidase and tyrosinase activity were determined to be 0.90 ± 0.03 mg/mL and 1.81 ± 0.02 mg/mL, respectively. Hyaluronidase mediates bacterial pathogenesis while coordinating critical physiological processes, including wound healing, inflammatory responses, and angiogenesis. Consequently, modulation of its activity represents a strategic therapeutic target for preserving skin integrity through maintenance of hyaluronic acid homeostasis and extracellular matrix architecture^[83]. And tyrosinase, a key enzyme in melanogenesis, catalyzes melanin biosynthesis, highlighting its relevance to skin whitening and lightening applications^[84].

Furthermore, the sun protection factor (SPF) was evaluated using the UV spectrophotometric technique, with the water extract being determined at wavelengths of 290 and 400 nm, which are crucial for the assessment of sunscreen efficacy. The findings revealed that the extract conferred a significant sun protection factor of 11.00 ± 0.03 at a concentration of 1,000 µg/mL^[82].

In 2024, Liu *et al.* investigated the anti-senescent properties of flavonoids in *P. utilis* seed residue (PURF) using a D-galactose-induced mouse aging model and a naturally senescent human foreskin fibroblast (HFF) model. PURF was found to elevate superoxide dismutase (SOD) levels and decrease hyaluronic acid (HYP) and malondialdehyde (MDA) levels. Expression analyses in HFF and 3D full T-Skin™ models revealed consistent upregulation of COL1A1, COL3A1, AMPK, and mTOR, alongside downregulation of TGF-β, MMP-1, MMP-9, p21, and p16. These results suggested that PURF modulates the AMPK/mTOR/TGF-β pathway, thereby exerting anti-senescent effects^[85].

4 Discussion and conclusion

P. utilis, native to the mountainous regions of China and the Himalayas, has been traditionally valued for its edible, medicinal, and cosmetic applications. This review synthesizes its phytochemical profile and biological activities, underscoring its potential in food, pharmaceutical, and cosmetic industries. Key constituents, including phenolic acids, flavonoids, anthocyanins, terpenoids, and γ-hydroxynitrile glucosides, demonstrate diverse bioactivities such as antioxidant, anti-inflammatory, antimicrobial,

and anti-senescent effects, positioning *P. utilis* as a promising candidate for functional foods, nutraceuticals, and cosmeceuticals. Currently, PUSO remains primarily confined to traditional culinary use, necessitating expanded foundational research to secure regulatory recognition. Scalable cultivation methods have been identified, with commercial production feasible post-approval from national authorities^[86].

However, current bioactivity studies are predominantly *in vitro*, lacking robust *in vivo* validation. Though *in vitro* assays reveal potent antioxidant and antimicrobial properties, translational applications face challenges such as uncharacterized absorption dynamics (e.g., metabolic instability of glycosides during digestion) and paradoxical thermal stability of cyanogenic compounds during oil processing. Future research must prioritize *in vivo* trials to validate safety and efficacy. Additionally, ethnomedicinal uses demand rigorous bioavailability studies to reconcile discrepancies between *in vitro* bioactivity and *in vivo* efficacy. Such research should clarify traditional-modern formulation gaps, guide functional product design, assess safety thresholds, and address regulatory requirements (e.g., bioequivalence standards) to enable *P. utilis*'s transition into precision phytotherapy.

Further investigation is needed into dose-dependent effects, mechanistic pathways, and spoilage mitigation strategies. Despite its use as a vegetable and tea in Yunnan's multi-ethnic communities, *P. utilis*'s low yield (currently wild-harvested) and perishability limit industrial scalability. Research should optimize extraction techniques, artificial cultivation, and food formulations to enhance bioactive stability without compromising sensory qualities. Systematic sensory evaluations (e.g., flavor profiling) are also critical to bridge ethnobotanical knowledge with evidence-based functional food development.

In summary, *P. utilis* exhibits significant potential for food and cosmetic innovation. Future efforts should focus on translating laboratory findings into practical applications, emphasizing functional product development that harnesses its bioactive properties to advance human health and nutrition.

Conflicts of interest

The authors declare that there are no conflicts of interest in this work. Haiyang Liu is an Editorial Board Member of Food & Medicine Homology, but was not involved in the processing, peer review or decision making of this article.

Acknowledgements

This work was financially supported by the Project of Yunnan Characteristic Plant Screening and R&D Service CXO Platform (No. 2022YKZY001), the Yunnan Revitalization Talent Support Program "Top Team" Project (No. 202305AT350001), and the Ten Thousand Talents Plan of Yunnan Province for Industrial Technology Leading Talents (No. YNWR-CYJS-2019-011).

References

- [1] Chen, G. Y., Liu, F. Y., Guo, Y. Study on the physicochemical properties of *Prinsepia utilis* Royle and its oil, and the fatty acid composition of its oil. *Cereals & Oils*, **2020**, 33: 69–71.
- [2] He, J. P., Li, Y., Wang, Y. P., et al. Germplasm resources of *Prinsepia utilis* Royle in Lijiang. *Journal of Agriculture*, **2020**, 10: 55–63. <https://doi.org/10.11923/j.issn.2095-4050.cjas19030008>
- [3] Zhang, X. P., Lin, X. M. Study of Qingcigu oil's function on blood lipid and other functions. *Journal of Hygiene Research*, **2005**, 34:

- 79–81. <https://doi.org/10.3969/j.issn.1000-8020.2005.01.028>
- [4] Tu, Y., An, R., Gu, H., et al. The water extracts from the oil cakes of *Prinsepia utilis* repair the epidermal barrier via up-regulating corneocyte envelope-proteins, lipid synthases, and tight junction proteins. *Journal of Ethnopharmacology*, **2024**, 330: 118194. <https://doi.org/10.1016/j.jep.2024.118194>
- [5] Bao, S. M., Gao, Q. F., Bao, J. F. Current status and development suggestions of *Prinsepia utilis* Royle resource exploitation in Luliang county. *Contemporary Horticulture*, **2021**, 44: 54–56. <https://doi.org/10.14051/j.cnki.xddy.2021.15.020>
- [6] Kunwar, R. M., Duwadee, N. P. S. Ethnobotanical notes on flora of Khaptad National Park, far-western Nepal. *Himalayan Journal of Sciences*, **2003**, 1: 25–30. <https://doi.org/10.3126/HJS.V1I1.182>
- [7] Guerriero, G., Berni, R., Muñoz-Sánchez, J. A., et al. Production of plant secondary metabolites: examples, tips and suggestions for biotechnologists. *Genes (Basel)*, **2018**, 9: 309. <https://doi.org/10.3390/genes9060309>
- [8] Neilson, A. P., Goodrich, K. M., Ferruzzi, M. G. Bioavailability and metabolism of bioactive compounds from foods. In: *Nutrition in the Prevention and Treatment of Disease (Fourth Edition)*. Academic Press, **2013**: 301–319
- [9] Kumar, N., Goel, N. Phenolic acids: Natural versatile molecules with promising therapeutic applications. *Biotechnology Reports*, **2019**, 24: e00370. <https://doi.org/10.1016/j.btre.2019.e00370>
- [10] Liu, X., Shi, J., Yi, J., et al. The effect of *in vitro* simulated gastrointestinal digestion on phenolic bioaccessibility and bioactivities of *Prinsepia utilis* Royle fruits. *LWT-Food Science and Technology*, **2021**, 138: 110782. <https://doi.org/10.1016/j.lwt.2020.110782>
- [11] Zheng, X. Q., Pan, F., Zhao, S., et al. Phenolic characterization, antioxidant and α -glycosidase inhibitory activities of different fractions from *Prinsepia utilis* Royle seed shell using *in vitro* and *in silico* analyses. *European Food Research and Technology*, **2023**, 249: 375–386. <https://doi.org/10.1007/s00217-022-04123-7>
- [12] Shen, W., Li, S. Y., Pan, Y. Q., et al. *Prinsepia utilis* Royle leaf extract: Ameliorative effects on allergic inflammation and skin lesions in allergic contact dermatitis and polyphenolic profiling through UPLC–MS/MS coupled to chemometric analysis. *Journal of Ethnopharmacology*, **2023**, 305: 116093. <https://doi.org/10.1016/j.jep.2022.116093>
- [13] Welch, A. A., Hardcastle, A. C. The effects of flavonoids on bone. *Current Osteoporosis Reports*, **2014**, 12: 205–210. <https://doi.org/10.1007/s11914-014-0212-5>
- [14] Panche, A. N., Diwan, A. D., Chandra, S. R. Flavonoids: an overview. *Journal of Nutritional Science*, **2016**, 5: e47. <https://doi.org/10.1017/jns.2016.41>
- [15] Santos, E. L., Maia, B. H. L. N. S., Ferriani, A. P., et al. *Flavonoids: classification, biosynthesis and chemical ecology* InTech, **2017**.
- [16] Braun, K. F., Ehnert, S., Freude, T., et al. Quercetin protects primary human osteoblasts exposed to cigarette smoke through activation of the antioxidative enzymes HO-1 and SOD-1. *The Scientific World Journal*, **2011**, 11: 2348–2357. <https://doi.org/10.1100/2011/471426>
- [17] Wong, S. K., Chin, K. Y., Ima-Nirwana, S. The osteoprotective effects of kaempferol: the evidence from *in vivo* and *in vitro* studies. *Drug Design, Development and Therapy*, **2019**, 13: 3497–3514. <https://doi.org/10.2147/DDDT.S227738>
- [18] Peng, Y., Peng, C., Wu, Y., et al. Chemical profiles of the active fraction from *Prinsepia utilis* Royle leaves and its anti-benign prostatic hyperplasia evaluation in animal models. *BMC Complementary Medicine and Therapies*, **2021**, 21: 272. <https://doi.org/10.1186/s12906-021-03446-4>
- [19] Zheng, Y., Zhao, L., Yi, J. Phytochemical characterization and antioxidant and enzyme inhibitory activities of different parts of *Prinsepia utilis* Royle. *Journal of Food Quality*, **2022**, 2022: 1–9. <https://doi.org/10.1155/2022/9739851>
- [20] Ma, S., Zheng, X., Zhang, Y., et al. Exploring the promotive effects and mechanisms of different polyphenolic extracts from *Prinsepia utilis* Royle seed shell on tyrosinase. *Foods*, **2022**, 11: 4015. <https://doi.org/10.3390/foods11244015>
- [21] Silva, L. M. P., Alves, J. S. F., Siqueira, E. M. D. S., et al. Isolation and identification of the five novel flavonoids from *Genipa americana* leaves. *Molecules*, **2018**, 23: 2521. <https://doi.org/10.3390/molecules23102521>
- [22] He, J., Giusti, M. M. Anthocyanins: natural colorants with health-promoting properties. *Annual Review of Food Science and Technology*, **2010**, 1: 163–187. <https://doi.org/10.1146/annurev.food.080708.100754>
- [23] Tsukasa, I. Flavonoid properties of five families newly incorporated into the order caryophyllales (Review). *Bulletin of the National Museum of Nature & Science*, **2013**, 39: 25–51.
- [24] Khoo, H. E., Azlan, A., Tang, S. T., et al. Anthocyanidins and anthocyanins: colored pigments as food, pharmaceutical ingredients, and the potential health benefits. *Food & Nutrition Research*, **2017**, 61: 90–21. <https://doi.org/10.1080/16546628.2017.1361779>
- [25] Giusti, M. M., Wrolstad, R. E. Acylated anthocyanins from edible sources and their applications in food systems. *Biochemical Engineering Journal*, **2003**, 14: 217–225. [https://doi.org/10.1016/S1369-703X\(02\)00221-8](https://doi.org/10.1016/S1369-703X(02)00221-8)
- [26] Dudareva, N., Andersson, S., Orlova, I., et al. The nonmevalonate pathway supports both monoterpene and sesquiterpene formation in snapdragon flowers. *Proceedings of the National Academy of Sciences of the United States of America*, **2005**, 102: 933–938. <https://doi.org/10.1073/pnas.0407360102>
- [27] Nina, T., Manuel, T. L. The evolution of function in plant secondary metabolites. *International Journal of Plant Sciences*, **2003**, 164: 93–102. <https://doi.org/10.1086/374190>
- [28] Zong, L., Cheng, L., Chen, Z. J., et al. Research progress on biosynthesis of terpenoids for food. *China Brewing*, **2018**, 37: 22–27. <https://doi.org/10.11882/j.issn.0254-5071.2018.09.005>
- [29] Gustafsson, D., Nyström, J., Carlsson, S., et al. The direct thrombin inhibitor melagatran and its oral prodrug H 376/95: intestinal absorption properties, biochemical and pharmacodynamic effects. *Thrombosis Research*, **2001**, 101: 171–181. [https://doi.org/10.1016/S0049-3848\(00\)00399-6](https://doi.org/10.1016/S0049-3848(00)00399-6)
- [30] Paduch, R., Kandefer-Szerszeń, M., Trytek, M., et al. Terpenes: substances useful in human healthcare. *Archivum Immunologiae et Therapiae Experimentalis*, **2007**, 55: 315–327. <https://doi.org/10.1007/s00005-007-0039-1>
- [31] Trombetta, D., Castelli, F., Sarpietro, M. G., et al. Mechanisms of antibacterial action of three monoterpenes. *Antimicrob Agents Chemother*, **2005**, 49: 2474–2478. <https://doi.org/10.1128/AAC.49.6.2474-2478.2005>
- [32] Kamińska, T., Kaczor, J., Rzeski, W., et al. A comparison of the antiviral activity of three triterpenoids isolated from *Betula alba* bark, **2004**
- [33] Jeppesen, P. B., Gregersen, S., Poulsen, C. R., et al. Stevioside acts directly on pancreatic beta cells to secrete insulin: actions independent of cyclic adenosine monophosphate and adenosine triphosphate-sensitive K^+ -channel activity. *Metabolism*, **2000**, 49: 208–214. [https://doi.org/10.1016/s0026-0495\(00\)91325-8](https://doi.org/10.1016/s0026-0495(00)91325-8)
- [34] Peana, A. T., D'Aquila, P. S., Chessa, M. L., et al. (–)-Linalool produces antinociception in two experimental models of pain. *European Journal of Pharmacology*, **2003**, 460: 37–41. [https://doi.org/10.1016/S0014-2999\(02\)02856-X](https://doi.org/10.1016/S0014-2999(02)02856-X)
- [35] Ziegler, H. L., Jensen, T. H., Christensen, J., et al. Possible artefacts in the *in vitro* determination of antimalarial activity of natural products that incorporate into lipid bilayer: apparent antiplasmodial activity of dehydroabietinol, a constituent of *Hyptis suaveolens*. *Planta Med*, **2002**, 68: 547–549. <https://doi.org/10.1055/s-2002-32548>
- [36] Xu, Y. Q., Yao, Z., Hu, J. Y., et al. Immunosuppressive terpenes from *Prinsepia utilis*. *Journal of Asian Natural Products Research*, **2007**, 9: 637–642. <https://doi.org/10.1080/10286020600979589>
- [37] Rai, V. K., Gupta, S. C., Singh, B. Volatile monoterpenes from *Prinsepia utilis* L. leaves inhibit stomatal opening in *Vicia faba* L. *Biologia Plantarum*, **2003**, 46: 121–124. <https://doi.org/10.1023/a:>

- 1022397730599
- [38] Zhang, Q., Liu, H. X., Tan, H. B., et al. Novel highly oxygenated and B-ring-*seco-ent*-diterpene glucosides from the seeds of *Prinsepia utilis*. *Tetrahedron*, **2015**, 71: 9415–9419. <https://doi.org/10.1016/j.tet.2015.10.055>
 - [39] Guan, B., Peng, C. C., Zeng, Q., et al. Cytotoxic pentacyclic triterpenoids from *Prinsepia utilis*. *Planta Medica*, **2013**, 79: 365–368. <https://doi.org/10.1055/s-0032-1328292>
 - [40] Morant, A. V., Bjarnholt, N., Kragh, M. E., et al. The β -Glucosidases responsible for bioactivation of Hydroxynitrile glucosides in *Lotus japonicus*. *Plant Physiology*, **2008**, 147: 1072–1091. <https://doi.org/10.1104/pp.107.109512>
 - [41] Nanna, B., Möller, B. L. Hydroxynitrile glucosides. *Phytochemistry*, **2008**, 69: 1947–1961. <https://doi.org/10.1016/j.phytochem.2008.04.018>
 - [42] Jones, P. R., Andersen, M. D., Nielsen, J. S., et al. The biosynthesis, degradation, transport and possible function of cyanogenic glucosides. *Recent Advances in Phytochemistry*, **2000**, 34: 191–247. [https://doi.org/10.1016/S0079-9920\(00\)80008-8](https://doi.org/10.1016/S0079-9920(00)80008-8)
 - [43] Guan, B., Li, T., Xu, X. K., et al. γ -Hydroxynitrile glucosides from the seeds of *Prinsepia utilis*. *Phytochemistry*, **2014**, 105: 135–140. <https://doi.org/10.1016/j.phytochem.2014.05.018>
 - [44] Shi, Q. Q., Lu, S. Y., Peng, X. R., et al. Hydroxynitrile glucosides: Bioactive constituent recovery from the oil residue of *Prinsepia utilis*. *Journal of Agricultural and Food Chemistry*, **2021**, 69: 2438–2443. <https://doi.org/10.1021/acs.jafc.0c07514>
 - [45] Gao, F. D., Zhang, C. T., Cai, S. B. Comparative analysis of multiple nutrients, phenolic compounds and antioxidant activities of the seeds and pomace of *Prinsepia utilis* Royle. *Food and Fermentation Industries*, **2019**, 45: 8. <https://doi.org/10.13995/j.cnki.11-1802/ts.017275>
 - [46] Günenc, A. N., Graf, B., Stark, H., Chari, A. Fatty acid synthase: structure, function, and regulation. *Subcell Biochem*, **2022**, 99: 1–33. https://doi.org/10.1007/978-3-031-00793-4_1
 - [47] Rustan, A. C., Drevon, C. A. Fatty acids: structures and properties. In: *The Encyclopedia of Life Sciences*. Wiley, **2020**.
 - [48] Zhang, X., Jia, Y., Ma, Y., et al. Phenolic composition, antioxidant properties, and inhibition toward digestive enzymes with molecular docking analysis of different fractions from *Prinsepia utilis* Royle fruits. *Molecules*, **2018**, 23: 3373. <https://doi.org/10.3390/molecules23123373>
 - [49] Huang, S., Ma, Y., Zhang, C., et al. Bioaccessibility and antioxidant activity of phenolics in native and fermented *Prinsepia utilis* Royle seed during a simulated gastrointestinal digestion *in vitro*. *Journal of Functional Foods*, **2017**, 37: 354–362. <https://doi.org/10.1016/j.jff.2017.08.004>
 - [50] Chen, C. Y., Chang, F., Teng, C., et al. Cheritamine, a new N - fatty acyl tryptamine and other constituents from the stems of *annona cherimola*. *Journal of The Chinese Chemical Society*, **1999**, 46: 77–86. <https://doi.org/10.1002/JCCS.199900010>
 - [51] Zhang, H. L., Nagatsu, A., Okuyama, H., et al. Sesquiterpene glycosides from cotton oil cake. *Phytochemistry*, **1998**, 48: 665–668. [https://doi.org/10.1016/S0031-9422\(98\)00075-2](https://doi.org/10.1016/S0031-9422(98)00075-2)
 - [52] Lechtenberg, M., Nahrstedt, A., Wray, V., et al. Cyanoglucosides from *Osmaronia cerasiformis* (rosaceae). *Phytochemistry*, **1994**, 37: 1039–1043. [https://doi.org/10.1016/S0031-9422\(00\)89525-4](https://doi.org/10.1016/S0031-9422(00)89525-4)
 - [53] Xie, W., Li, J., Li, H. M. Study on chemical constituents of *Smallanthus sonchifolius*. *Journal of Chinese medicinal materials*, **2008**, 31: 1510–1512. <https://doi.org/10.13863/j.issn1001-4454.2008.10.025>
 - [54] Kildidar, S. B., Parthasarathy, M. R., Sharma, P. Prinsepiol, a lignan from stems of *Prinsepia utilis*. *Phytochemistry*, **1982**, 21: 796–797. [https://doi.org/10.1016/0031-9422\(82\)83196-8](https://doi.org/10.1016/0031-9422(82)83196-8)
 - [55] Hargrave, J. D., Herbert, J., Bish, G., Frost, C. G. Rhodium-catalysed addition of organotrialkoxysilanes to α -substituted acrylic esters. *Organic & Biomolecular Chemistry*, **2006**, 4: 3235–3241. <https://doi.org/10.1039/b606977k>
 - [56] Yamasaki, K., Kasai, R., Masaki, Y., et al. Application of C-13 NMR to the structural elucidation of acylated plant glycosides. *Tetrahedron Letters*, **1977**, 18: 1231–1234. [https://doi.org/10.1016/S0040-4039\(01\)92983-1](https://doi.org/10.1016/S0040-4039(01)92983-1)
 - [57] Lalonde, R. T., Perakyla, H., Hayes, M. P. Potentially mutagenic, chlorine-substituted 2(5H)-furanones: studies of their synthesis and NMR properties. *The Journal of Organic Chemistry*, **1990**, 55: 2847–2855. <https://doi.org/10.1021/jo00296a053>
 - [58] Pan, H., Zhao, Y. Q. Chemical constituents in immature fruits of *Momordica charantia*. *Chinese Traditional & Herbal Drugs*, **2007**, 38: 9–11.
 - [59] Liang, J., Zhen, H. S., Zhang, W. W., et al. Studies on chemical constituents of ethyl acetate extract in the roots of *Actinidia Deliciosa* in Guangxi. *Lishizhen Medicine and Materia Medica Research*, **2008**, 32: 1544–1546.
 - [60] Yang, H., Feng, J. The exploitation and ethno-botany examination on *Prinsepia utilis* Royle. *Journal of Xichang University (Natural Science Edition)*, **2007**: 84–86.
 - [61] He, J. L., Liu, Z. D., Wang, B. Study on fatty acid composition and storage stability of *Prinsepia utilis* Royle oil. *Cereals & Oils*, **2017**, 30: 72–74.
 - [62] He, Q. J., He, J. W., Wang, Y. P., et al. Overview of *Prinsepia utilis* Royle. *Chinese Agricultural Science Bulletin*, **2016**, 32: 74–78. <https://doi.org/10.11924/j.issn.1000-6850.casb15080127>
 - [63] Luo, C. J., Lin, H. Q., Yu, C. Q., et al. Comparative research on seed oil of *Prinsepia utilis* prepared by supercritical fluid extraction, ultrasonic extraction and squeezing methods. *Journal of Anhui Agricultural Sciences*, **2015**, 43: 2. <https://doi.org/10.3969/j.issn.0517-6611.2015.29.008>
 - [64] Yang, W. U., Peng, Y., Peng, C. S., et al. Screening active components from *Prinsepia utilis* Royle leaves for combating benign prostatic hyperplasia in rats. *Modern Food Science and Technology*, **2019**.
 - [65] Zhu, Z. L., Fan, J., Zhang, H. F. Freshness-keeping effect of ethanol-extracted substances from *Prinsepia utilis* Royle on peach. *Journal of Southwest University (Natural Science Edition)*, **2002**, 24: 442–444. <https://doi.org/10.1006/jfls.2001.0409>
 - [66] Wu, S., Shen, D., Wang, R., et al. Phenolic profiles and antioxidant activities of free, esterified and bound phenolic compounds in walnut kernel. *Food Chemistry*, **2021**, 350: 129217. <https://doi.org/10.1016/j.foodchem.2021.129217>
 - [67] Bagale, R., Acharya, S., Gupta, A., et al. Antibacterial and antioxidant activities of *Prinsepia utilis* Royle leaf and seed extracts. *Journal of Tropical Medicine*, **2022**, 2022: 3898939. <https://doi.org/10.1155/2022/3898939>
 - [68] Pu, Z., Yin, Z., Jia, R., et al. Preliminary isolation and antibacterial activity of the ethyl acetate extract of *Prinsepia utilis* Royle *in vitro*. *Agricultural Sciences*, **2014**, 5: 540–545. <https://doi.org/10.4236/AS.2014.56056>
 - [69] Zhang, C. T., Ma, Y. L., Gao, F. D., et al. The free, esterified, and insoluble-bound phenolic profiles of *Rhus chinensis* Mill. fruits and their pancreatic lipase inhibitory activities with molecular docking analysis. *Journal of Functional Foods*, **2018**, 40: 729–735. <https://doi.org/10.1016/j.jff.2017.12.019>
 - [70] Sosnowska, M. K., Alicja Z. Inhibitory effect of black chokeberry fruit polyphenols on pancreatic lipase searching for most active inhibitors. *Journal of Functional Foods*, **2018**, 49: 196–204. <https://doi.org/10.1016/j.jff.2018.08.029>
 - [71] Chauhan, N. Important medicinal and aromatic plants of Himachal Pradesh. *The Indian Forester*, **2003**, 129: 979–998.
 - [72] Sharma, P. K., Chauhan, N., Lal, B. Studies on plant associated indigenous knowledge among the Malanis of Kullu district, Himachal Pradesh. *Indian journal of traditional knowledge*, **2005**, 4: 403–408.
 - [73] Gupta, R., Goyal, R., Bhattacharya, S., et al. Antioxidative *in vitro* and antiosteoporotic activities of *Prinsepia utilis* Royle in female rats. *European Journal of Integrative Medicine*, **2015**, 7: 157–163. <https://doi.org/10.1016/j.eujim.2014.10.002>
 - [74] Chen, R., Jia, R. Y., Yin, Z. Q., et al. Influence of polysaccharides

- from *Prinsepia utilis* Royle on pathological changes in the lungs of diabetic mice. *Journal of Southwest University (Natural Science Edition)*, **2007**, 29: 5. <https://doi.org/10.3969/j.issn.1673-9868.2007.12.015>
- [75] Zhang, L. Research on the moisturizing effects of prickly kernel oil. *Detergent & Cosmetics*, **2008**, 10: 22–25. <https://doi.org/10.3969/j.issn.1006-7264.2008.10.007>
- [76] Guillaume, D., Charrouf, Z. Argan oil and other argan products: Use in dermocosmetology. *European Journal of Lipid Science and Technology*, **2011**, 113: 403–408.
- [77] Kishimoto, R., Kato, N., Koike, M., et al. Topical treatment with mastic (resin from *Pistacia lentiscus*) elicits anti-inflammatory and anti-pruritic responses by modulating keratinocyte activation in a mouse model of allergic dermatitis. *Phytomedicine*, **2021**, 91: 153679. <https://doi.org/10.1016/j.phymed.2021.153679>
- [78] Mariana, B., Graciliana, L., Patrícia, V. O., et al. Edible seaweeds' phlorotannins in allergy: A natural multi-target approach. *Food Chemistry*, **2018**, 265: 233–241. <https://doi.org/10.1016/j.foodchem.2018.05.074>
- [79] Obaid, R. J., Mughal, E. U., Naeem, N., et al. Natural and synthetic flavonoid derivatives as new potential tyrosinase inhibitors: a systematic review. *RSC Advances*, **2021**, 11: 22159–22198. <https://doi.org/10.1039/d1ra03196a>
- [80] Qu, Y., Zhan, Q., Du, S., et al. Catalysis-based specific detection and inhibition of tyrosinase and their application. *Journal of Pharmaceutical Analysis*, **2020**, 10: 414–425. <https://doi.org/10.1016/j.jpha.2020.07.004>
- [81] Tu, Y., Gu, H., Li, N., et al. Effects of *Prinsepia utilis* Royle oil on the synthesis of ceramide and expression of ceramidase. *Chinese Journal of Dermatology*, **2012**, 45: 5. <https://doi.org/10.3760/cma.j.issn.0412-4030.2012.10.012>
- [82] Kewlani, P., Singh, L., Singh, B., et al. Sustainable extraction of phenolics and antioxidant activities from *Prinsepia utilis* byproducts for alleviating aging and oxidative stress. *Sustainable Chemistry and Pharmacy*, **2022**, 29: 100791. <https://doi.org/10.1016/j.scp.2022.100791>
- [83] Bravo, K., Alzate, F., Osorio, E. Fruits of selected wild and cultivated Andean plants as sources of potential compounds with antioxidant and anti-aging activity. *Industrial Crops and Products*, **2016**, 85: 341–352. <https://doi.org/10.1016/j.indcrop.2015.12.074>
- [84] Ahmed, I. A., Mikail, M. A., Zamakshshari, N., et al. Natural anti-aging skincare: role and potential. *Biogerontology*, **2020**, 21: 293–310. <https://doi.org/10.1007/s10522-020-09865-z>
- [85] Liu, J., Qu, L., Wang, F., et al. A study on the anti-senescent effects of flavones derived from *Prinsepia utilis* Royle seed residue. *Journal of Ethnopharmacology*, **2024**, 328: 118021. <https://doi.org/10.1016/j.jep.2024.118021>
- [86] Yang, J. H., Fan, Z. Y., Li, S. F., et al. Study on cultivation techniques for *Prinsepia utilis* Royle. *Chinese Wild Plant Resources*, **2011**, 30: 4. <https://doi.org/10.3969/j.issn.1006-9690.2011.02.018>