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Review Article

A comprehensive review on traditional uses, botany, chemical constituents, pharmacology of turnip (*Brassica rapa* L.)

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Abstract: Turnip (*Brassica rapa* L.) is a cruciferous Brassica plant, which is often used as medicine and food in the plateau area of China. It has anti-cancer, anti-hypoxia, anti-oxidation, anti-bacterial and anti-inflammatory activities. However, the current medicinal research and development of turnip is not comprehensive, and the future research direction is not clear. Therefore, this paper used “radish” and “*Brassica rapa* L.” as search terms to conduct searches in the literature databases such as Google Scholar, Web of Science, PubMed, China National Knowledge Infrastructure and Wanfang Data. At the same time, various related books are consulted to screen and integrate the required information. In this paper, phytochemical studies have summarized 113 compounds of turnip, including flavonoids and their glycosides, polysaccharides, glucosinolates and their breakdown products, organic acids, and other chemical constituents. Turnip has a wide range of pharmacological effects, including anti-cancer, anti-hypoxia, anti-oxidant, and hypoglycemic effects. In addition, this paper also puts forward the suggestions for the follow-up research in order to provide reference for the follow-up research.

Keywords: turnip; traditional uses; phytochemistry; pharmacology

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1 Introduction

Turnip (*Brassica rapa* L.), also known as “Chamagou” or “round root”, is a Cruciferae (*Brassicaceae*) Brassica (*Brassica*) biennial herbaceous plant, native to Europe and currently cultivated throughout our country. Its fleshy roots are a common food for ethnic minorities in the Asian plateau region and can be cooked, pickled, or used as livestock fodder[1,2]. *The Dictionary of Traditional Chinese Medicine* records that turnip roots, flowers, leaves, and seeds can be used as medicine and have many benefits to the human body, which is known as “small ginseng” by the local people and can relieve fatigue and prevent hypoxia[3]. It is recorded in *Uygur Pharmacognosy* that turnip can be used to treat cough, physical deficiency, dreaminess and so on[4]. Modern studies have shown that turnip contains many types of chemical constituents such as flavonoids, glucosinolates[5], polysaccharides[6], organic acids, etc.[7], and in terms of bioactivities, turnip shows potential medicinal activities in anti-cancer, anti-hypoxia, anti-oxidant, hypoglycemic, and neuroprotective aspects[8,9].

In recent years, the research of turnip in medicine has gradually increased, for example, it has been pointed out that turnip polysaccharides have good anti-hypoxia[3], anti-oxidation[5], and anti-cancer activities[10], especially its anti-hypoxia activity. More and more studies have confirmed that turnip has the potential to be developed as a drug to improve the symptoms of hypoxia. At this stage, new components and pharmacological activities of turnip have been discovered[11,12], which indicates that the medicinal value of turnip has been discovered and recognized by more researchers, so it should be continued to explore its potential of preventing or treating diseases at a deeper level[6,7], which will make a certain contribution to the Chinese medicine industry and human health. In this paper, we present a review of the relevant studies on turnip in recent years, reporting on traditional uses, botany, phytochemistry, pharmacology, and application prospects, with the aim of providing references for its subsequent development and medicinal research.

2 Materials and methods

To comprehensively search the current research status of turnip, we searched China Knowledge, Google Scholar, Wanfang Data, PubMed, Web of Science, SpringerLink, and other databases to search the chemical composition, pharmacological activity of turnip and other related information. Information on the

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traditional uses, botany and other information of turnip was searched in databases and books such as Chinese Traditional Medicine Ancient Books and Chinese Materia Medica. "Turnip", "chamagou", "chemical composition", "pharmacological effect", "traditional use", etc., were used as search terms without language limitation, the retrieved literature information that meets the requirements is summarized and analyzed to obtain the current status of turnip-related research, and after the integration of a total of 106 cited literature, the flowchart used to determine the cited literature is shown in Fig. 1. Chemical structures were drawn using ChemDraw Professional 20.0.

3 Traditional uses

As a medicinal plant, its medicinal use and efficacy have been recorded in many Chinese ancient books, combined with literature analysis of ancient books can be found that turnip is usually not complex processing and concocting, boiled for internal use or crushed externally can be used in the treatment of fever, swelling, dysuria and so on, the application of a greater number of applications and the efficacy is good[13].

The turnip was first published in *Mingyi Bielu* as a superior medicinal herb. *Chinese herbal medicine* records that turnip is bitter, pungent and sweet in taste, with a mild nature, can stimulate appetite, diuresis and detoxification, treatment of food accumulation, jaundice, fever and swelling[4]. A hundred years of Tibetan medicine classics *Pharmacopoeia in Four Divisions* points out that turnip has the effect of anti-plateau reaction, anti-hyperlipidemia and anti-fatigue[14]. The *Qianjin Fang* mentions that turnip can also be used to treat head baldness sores of pediatrics[15]. In addition, turnip seeds can also be used to treat diseases, such as alleviating various food poisoning[16], improving hair quality, wrinkles, facilitating urination, and improving eyesight[17-19]. Turnip can not only be used individually, but also grouped to play a role in the therapeutic effect of the prescription, such as *Taiping Shenghui Fang*, which records that Huanglian Cake, etc., contains turnip root, they can treat swelling and poison[20,21]; turnip root can also be used in the medicine of Diyu Drink, treating Pediatric parasitic blood dysentery.

Turnip has a long history of dual use of medicine and food, in addition to the above documented uses, modern turnip-based traditional Chinese medicine products include turnip honey paste, turnip essential oil, turnip capsule, and turnip powder, which are mostly used in the field of health care and beauty care with antioxidant, antibacterial, and anti-inflammatory, immune regulation, etc. Modern research on the medicinal use of turnip is still in the initial stage, and there is a lack of research on traditional Chinese medicine preparations and practical clinical experience[22-24].

4 Botany

Turnip is a 2-year-old herb, up to 90 cm tall, with fleshy, spherical, oblate, or sometimes long elliptic tuberous roots, and fibrous roots usually growing on a taproot below the tuberous roots. The stem is erect, branched, slightly hairy in the lower part and glabrous in the upper part. Basal leaves lyrate or compound, 20–34 cm long, terminal lobe or leaflet large, margin undulate or lobed, lateral lobes or leaflets about 5 pairs, tapering downward, scattered with prickly hairs, petiole 10–16 cm long, with lobules. Middle and upper cauline leaves oblong-lanceolate, 3–12 cm long, glabrous, pruinose, base broadly cordate, semiclasping to clasping. Racemes terminal, flowers small, bright yellow about 7 mm; sepals 4, distichous, spreading; petals 4, cruciform, long-clawed; stamens 6, 4-strong; pistil 1, ovary superior, 1-loculed, pseudo-2-loculed by a membranous septum. Long-horned fruit terete, 3.5–6 cm long, beak slender. Seeds globose, about 1.8 mm in diameter, light yellowish brown, black near the umbilicus, with finely reticulate areoles; flowering in spring. The flowers and seeds are also used medicinally[4] (Fig. 2).

A study was conducted on the microscopic identification of turnip herbs, and the microscopic examination of the crude powder of turnip showed that the starch grains were numerous, spherical or oblong, with diameters ranging from 6 to 25 μm, the

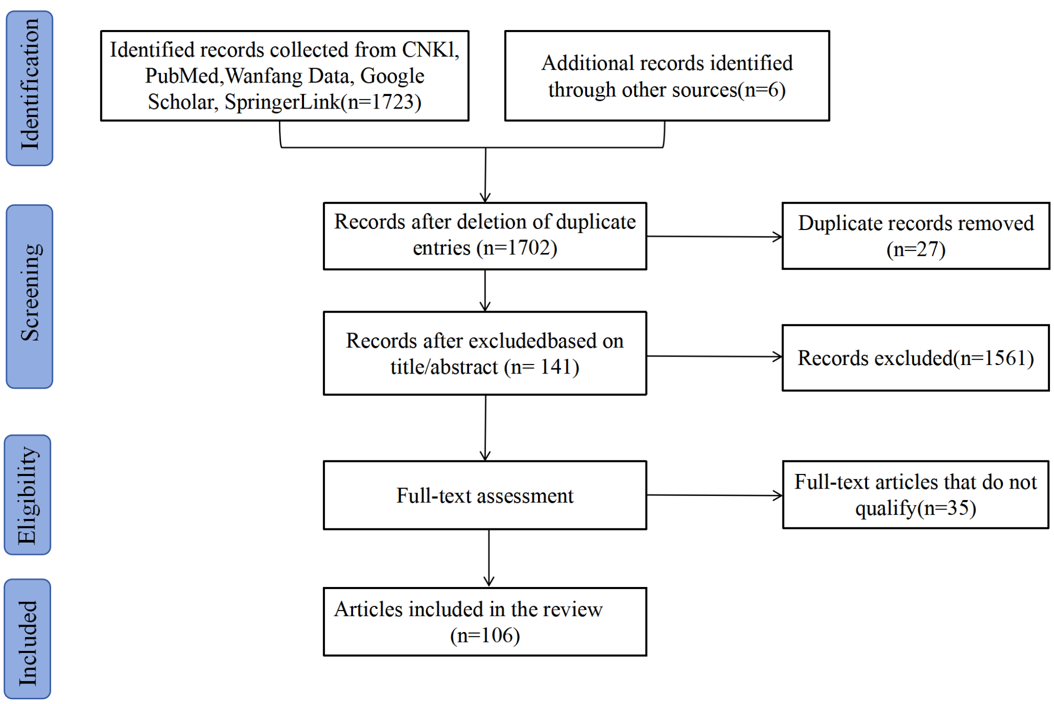


Figure 1 Research data search & selection flow.

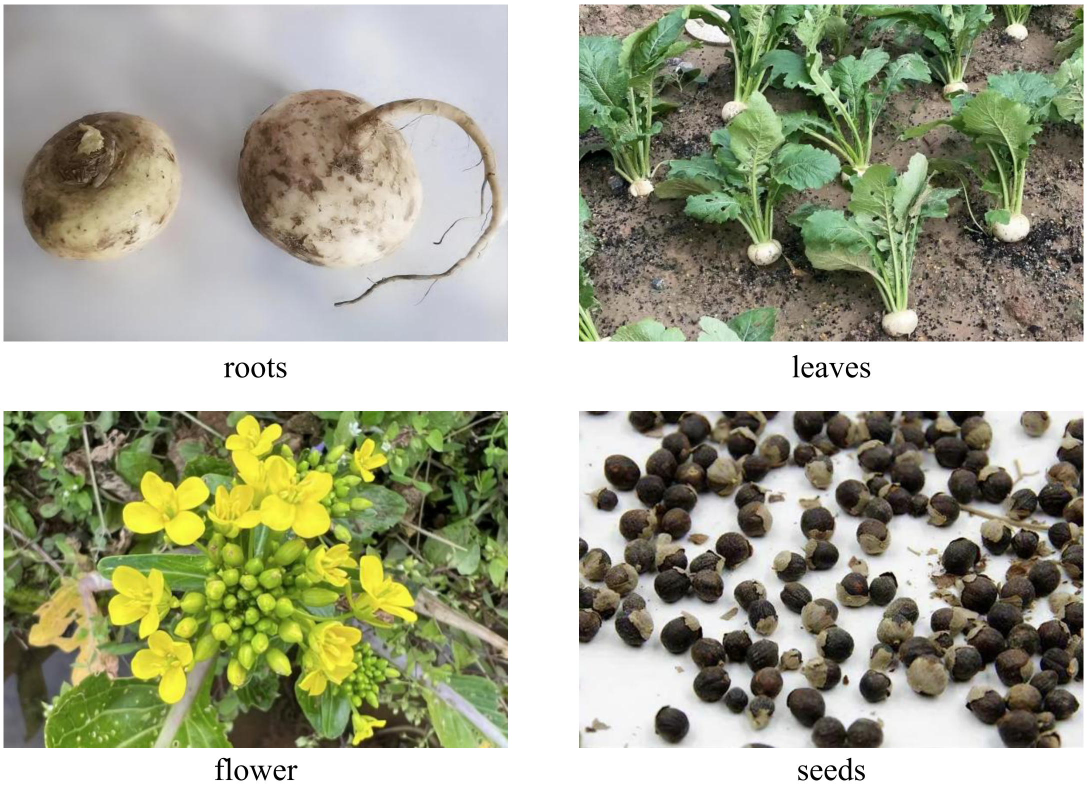


Figure 2 *Brassica rapa* L. plant.

umbilical point was obvious, mostly herringbone, and the complex grains were composed of 2–7 meristematic grains. The cork cells were colorless and yellowish, long polygonal. Reticulated conduits were the most common, and there were also ciliated conduits with ciliated pores, with diameters ranging from 9–127 μm. The square crystals are more frequent and are rhomboidal, polygonal, oblong-like and irregular. They range from about 18 μm in diameter to 29 μm in length[25].

5 Phytochemistry

5.1 Flavonoids

Flavonoids are common secondary metabolites in plants and are widely found in roots, bark, leaves and seeds. The current study found that the first major group of components contained in turnip is flavonoids, mainly quercetin, kaempferol, isorhamnetin, and most of them are glycosylated or acylated by different hydroxycinnamic acids[26]. For example, most of the compounds isolated from the methanolic extract of turnip by alkaline hydrolysis were identified as glycosylated flavonoids[27]. Wang used response surface optimization method to derive the optimal extraction method for turnip flavonoids, which yielded up to 2.8 mg/g of turnip flavonoids[28]. In this paper, 40 major flavonoid constituents including kaempferol-3-*O*-sophoroside, kaempferol-3-*O*-glucoside, kaempferol-7-*O*-glucoside, etc., were compiled as shown in Table 1 and Fig. 3.

5.2 Polysaccharides

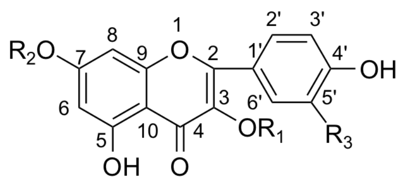
Polysaccharides, as a kind of widespread natural polymer

Table 1 Flavonoids in turnip

No.	Compound	Molecular	MW (g/mol)	Resources	Solvents	Reference
1	Kaempferol-3-*O*-sophoroside	$C_{27}H_{30}O_{16}$	611	leaves, flower	70% methanol,70% ethanol	[27, 29]
2	Kaempferol-3-*O*-glucoside	$C_{21}H_{20}O_{11}$	448	leaves, flower	70% methanol, 70% ethanol	[27, 29]
3	Kaempferol-7-*O*-glucoside	$C_{21}H_{20}O_{11}$	448	leaves	70% methanol	[27]
4	Kaempferol-3-*O*-rutinose	$C_{27}H_{30}O_{15}$	595	seeds	95% ethanol	[30]
5	Kaempferol-3,7-di-*O*-glucoside	$C_{27}H_{30}O_{16}$	610	leaves, flower	70% methanol, 70% ethanol	[27, 29]
6	kaempferol-3-*O*-sophoroside-7-*O*-glucoside	$C_{33}H_{40}O_{21}$	773	leaves, flower	70% methanol, 70% ethanol	[27, 29]
7	Kaempferol-3-*O*-sophoroside-7-*O*-sophoroside	$C_{39}H_{50}O_{26}$	935	leaves, stems, flower, roots	water	[31, 32]
8	Kaempferol-3-*O*-triglucoside-7-*O*-glucoside	$C_{39}H_{50}O_{26}$	935	leaves	70% methanol	[27]
9	Kaempferol-3-*O*-(feruloyl)sophoroside	$C_{37}H_{38}O_{19}$	787	leaves, flower	70% methanol, 70% ethanol	[27, 29]
10	Kaempferol-3-*O*-(caffeoyl)sophoroside	$C_{37}H_{39}NO_{17}$	770	leaves, flower	70% methanol, 70% ethanol	[27, 29]
11	Kaempferol-3-*O*-(sinapoyl)sophoroside	$C_{38}H_{40}O_{20}$	817	leaves, flower	70% methanol, 70% ethanol	[27, 29]
12	Kaempferol-3-*O*-(p-coumaroyl)sophoroside	$C_{36}H_{36}O_{18}$	757	leaves	70% methanol	[27]

(Continued)

No.	Compound	Molecular	MW (g/mol)	Resources	Solvents	Reference
13	Kaempferol-3-*O*-(methoxycaffeoyl)sophoroside	$C_{31}H_{28}O_{16}$	657	leaves	70% methanol	[27]
14	Kaempferol-3-*O*-(methoxycaffeoyl)sophoroside-7-*O*-glucoside	$C_{37}H_{38}O_{21}$	819	leaves, flower	70% methanol, 70% ethanol	[27, 29]
15	Kaempferol-3-*O*-(sinapoyl)sophoroside-7-*O*-glucoside	$C_{44}H_{50}O_{25}$	979	leaves, flower	70% methanol, 70% ethanol	[27, 29]
16	Kaempferol-3-*O*-(feruloyl)sophoroside-7-*O*-glucoside	$C_{43}H_{48}O_{24}$	949	leaves	70% methanol	[27]
17	Kaempferol-3-*O*-(caffeoyl)sophoroside-7-*O*-glucoside	$C_{43}H_{49}NO_{22}$	932	leaves	70% methanol	[27]
18	Kaempferol-3-*O*-(p-coumaroyl)sophoroside-7-*O*-glucoside	$C_{42}H_{46}O_{23}$	919	leaves	70% methanol	[27]
19	Quercetin-3-*O*-sophoroside	$C_{27}H_{30}O_{17}$	627	leaves	70% methanol	[27]
20	Quercetin-7-*O*-glucoside	$C_{21}H_{20}O_{12}$	464	leaves	70% methanol	[27]
21	Quercetin-3,7-di-*O*-glucoside	$C_{27}H_{30}O_{17}$	627	leaves	70% methanol	[27]
22	Quercetin-3-*O*-sophoroside-7-*O*-glucoside	$C_{33}H_{40}O_{22}$	789	leaves	70% methanol	[27]
23	Quercetin-3-*O*-(feruloyl)sophoroside	$C_{37}H_{38}O_{20}$	803	leaves	70% methanol	[27]
24	Quercetin-3-*O*-(caffeoyl)sophoroside-7-*O*-glucoside	$C_{37}H_{39}NO_{18}$	786	leaves	70% methanol	[27]
25	Quercetin-3-*O*-(p-coumaroyl)sophoroside-7-*O*-glucoside	$C_{42}H_{46}O_{24}$	935	leaves, flower	70% methanol, 70% ethanol	[27, 29]
26	Quercetin-3-*O*-(sinapoyl)sophoroside-7-*O*-glucoside	$C_{44}H_{50}O_{26}$	995	leaves, flower	70% methanol, 70% ethanol	[27, 29]
27	Quercetin-3-*O*-(feruloyl)sophoroside-7-*O*-glucoside	$C_{43}H_{48}O_{25}$	965	leaves, flower	70% methanol, 70% ethanol	[27, 29]
28	Quercetin-3-*O*-(methoxycaffeoyl)sophoroside-7-*O*-glucoside	$C_{43}H_{48}O_{26}$	981	leaves	70% methanol	[27]
29	Isorhamnetin-3-*O*-glucoside	$C_{22}H_{22}O_{12}$	478	leaves, flower	70% methanol, 70% ethanol	[27, 29]
30	Isorhamnetin-7-*O*-glucoside	$C_{22}H_{22}O_{12}$	478	leaves	70% methanol	[27]
31	Isorhamnetin-3,7-di-*O*-glucoside	$C_{28}H_{32}O_{17}$	641	leaves	70% methanol	[27, 33]
32	4,4′-dihydroxy-3′-methoxychalcone	$C_{16}H_{14}O_4$	270	roots	95% ethanol	[34]
33	4′-*O*-*β*-d-pyranyl-3′,4-dimethoxychalcone	$C_{23}H_{26}O_9$	447	leaves	methanol	[35]
34	4′-*O*-*β*-D-glucopyranosyl-4-hydroxy-3′-methoxychalcone	$C_{22}H_{24}O_9$	432	leaves	methanol	[35]
35	4,4′-2-*O*-*β*-d-pyranyl glucosyl-3′-methoxychalcone	$C_{28}H_{34}O_{14}$	595	leaves	methanol	[35]
36	licochalcone A	$C_{21}H_{22}O_4$	338	roots	70% ethanol	[36]
37	5-hydroxyl-3′,4′,6,7-tetramethoxyflavonoids	$C_{19}H_{18}O_7$	359	seeds	95% ethanol	[30]
38	liquiritin	$C_{21}H_{22}O_9$	418	roots	70% ethanol	[36]
39	liquiritigenin	$C_{15}H_{12}O_4$	256	leaves, flower	70% ethanol	[29]
40	Isoliquiritin	$C_{21}H_{22}O_9$	418	leaves, flower	70% ethanol	[29]



1	2	3	4
R_1=sophorosyl R_2=H R_3=H	R_1=glucosyl R_2=H R_3=H	R_1=H R_2=glucosyl R_3=H	R_1=rutinose R_2=H R_3=H
5	**6**	**7**	**8**
R_1=glucosyl R_2=glucosyl R_3=H	R_1=sophorosyl R_2=glucosyl R_3=H	R_1=sophorosyl R_2=sophorosyl R_3=H	R_1=triglucosyl R_2=glucosyl R_3=H
9	**10**	**11**	**12**
R_1=(feruloyl)sophorosyl R_2=H R_3=H	R_1=(caffeoyl)sophorosyl R_2=H R_3=H	R_1=(sinapoyl)sophorosyl R_2=H R_3=H	R_1=(p-coumaroyl)sophorosyl R_2=H R_3=H

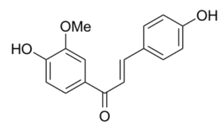
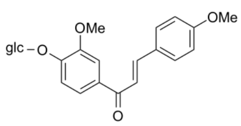
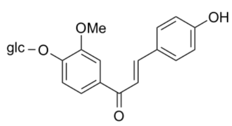
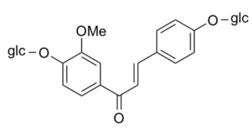
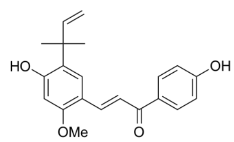
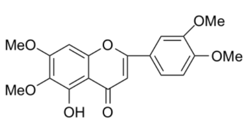
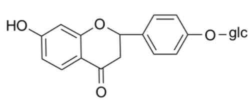
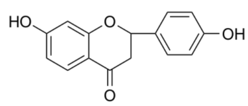
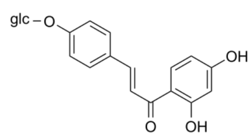
13	14	15	16
R_1=(methoxycaffeoyl)sophorosyl R_2=H R_3=H	R_1=(methoxycaffeoyl)sophorosyl R_2=glucosyl R_3=H	R_1=(sinapoyl)sophorosyl R_2=glucosyl R_3=H	R_1=(feruloyl)sophorosyl R_2=glucosyl R_3=H
17	**18**	**19**	**20**
R_1=(caffeoyl)sophorosyl R_2=glucosyl R_3=H	R_1=(p-coumaroyl)sophorosyl R_2=glucosyl R_3=H	R_1=sophorosyl R_2=H R_3=OH	R_1=H R_2=glucosyl R_3=OH
21	**22**	**23**	**24**
R_1=glucosyl R_2=glucosyl R_3=OH	R_1=sophorosyl R_2=glucosyl R_3=OH	R_1=(feruloyl)sophorosyl R_2=H R_3=OH	R_1=(caffeoyl)sophorosyl R_2=glucosyl R_3=OH
25	**26**	**27**	**28**
R_1=(p-coumaroyl)sophorosyl R_2=glucosyl R_3=OH	R_1=(sinapoyl)sophorosyl R_2=glucosyl R_3=OH	R_1=(feruloyl)sophorosyl R_2=glucosyl R_3=OH	R_1=(methoxycaffeoyl)sophorosyl R_2=glucosyl R_3=OH
29	**30**	**31**	**32**
R_1=glucosyl R_2=H R_3=OMe	R_1=H R_2=glucosyl R_3=OMe	R_1=glucosyl R_2=glucosyl R_3=OMe	
33	**34**	**35**	**36**
			
37	**38**	**39**	**40**
			

Figure 3 Chemical structure of flavonoids in turnip.

compound, have a variety of pharmacological activities. For example, they can show significant anti-cancer activity in turnip, etc.[37]. Turnip polysaccharides are a class of complex polysaccharides isolated from the tuberous roots and seeds of turnip with a rich variety of species, and their mass fraction as one of the main active components of turnip is about 9.8% to 10.5%[38, 39]. In a study by Wang, the optimal extraction process for turnip polysaccharides was determined with a crude extraction rate of about 21.48 ± 0.41%[40]. Kong *et al.* used this method to extract crude polysaccharides from turnip, and the content of saccharuronic acid was measured to be 34.36 ± 0.08% by m-hydroxybiphenyl method, and the extract consisted of fucose (Fuc), rhamnose (Rha), arabinose (Ara), glucosamine hydrochloride (GlcN), galactose (Gal), glucose (Glc), N-acetyl-D-glucosamine (GlcNAc), xylose (Xyl), and guluronic acid (GulA) in molar ratios of approximately 0.004: 0.023: 0.233: 0.003: 0.211: 0.229: 0.013: 0.035: 0.250[11]. Li used 1-phenyl-3-methyl-5-pyrazolone (PMP) pre-column derivatization high-performance liquid chromatography (HPLC) to detect the turnip samples and analyzed the monosaccharides of turnip polysaccharides to be composed of mannose, rhamnose, galacturonan, anhydrous glucose, galactose and arabinose, with a molar ratio of 0.0096: 0.39: 1: 1.39: 0.33: 0.16[41].

5.3 Glucosinolates and isothiocyanates

Glucosinolates are a class of N, S-containing glucose derivatives in cruciferous plants, which are broadly categorized into aliphatic, aromatic, and indolic glucosinolates according to the differences in the moieties of each component. The glucosinolate-black mustard enzyme system is considered to be an important defense system in cruciferous plants. Damaged cells of turnips secrete a compound called black mustard enzyme (β-thioglucosidase), which hydrolyzes the glucosinolates to isothiocyanate, indole, nitrile, and thiocyanate products, which have a special odor that reduces insect damage to the plant and is a characteristic of this group of plants. The 3-butenyl isothiocyanate is the main volatile component[42, 43]. Francisco extracted turnip by leaching with 70% methanol at 70 °C, and finally isolated and identified glucosinolates from the dried powder[27]. Wang used the response surface optimization method, and finally arrived at the optimal process for extracting turnip glucosinolates, which yielded 14.38 μmol/g glucosinolates[28]. Current studies have shown that glucosinolates and their hydrolyzed products have health benefits such as anticancer, antimicrobial, and antioxidant properties[44]. The major glucosinolates of turnip and their breakdown products isothiocyanates, are presented in Table 2 and Fig. 4. 41–60 are glucosinolates, and 61–79 are isothiocyanates.

5.4 Organic acids

Turnip is rich in organic acids, including malic acid, mangiferic acid, aconitic acid, etc. The types and contents of organic acids contained in different parts of turnip vary greatly, and studies have shown that the total organic acid content of turnip buds, stems, and leaves is about 36–51 g/kg (dried), and that the content of malic acid in the roots (81%) is significantly higher than in the leaves and stems (65%), whereas the aconitic acid in the flower

Table 2 Glucosinolates and isothiocyanates in turnip

No.	Component	Molecular	MW (g/mol)	Resources	Solvents	Reference
41	Glucoraphanin	$C_{12}H_{23}NO_{10}S_3$	438	leaves	70% methanol	[27, 45]
42	Glucotropaeolin	$C_{14}H_{19}NO_9S_2$	409.	leaves	70% methanol	[27]
43	Gluconasturtiin	$C_{15}H_{21}NO_9S_2$	424	leaves	70% methanol	[27, 45]
44	Gluconapin	$C_{11}H_{19}NO_9S_2$	373	leaves	70% methanol	[27, 45]
45	Epiprogoitrin	$C_{11}H_{19}NO_{10}S_2$	389	leaves	70% methanol	[27, 45]
46	Neoglucobrassicin	$C_{17}H_{22}N_2O_{10}S_2$	479	leaves	70% methanol	[27, 45]
47	Glucobrassicin	$C_{16}H_{20}N_2O_9S_2$	449	leaves	70% methanol	[27, 45]
48	Gluconapoleiferin	$C_{12}H_{21}NO_{10}S_2$	403	leaves	70% methanol	[27, 45]
49	Progoitrin	$C_{11}H_{19}NO_{10}S_2$	389	leaves	70% methanol	[27, 45]
50	Glucobrassicanapin	$C_{12}H_{21}NO_9S_2$	387	leaves	70% methanol	[27, 45]
51	4-Hydroxyglucobrassicin	$C_{16}H_{20}N_2O_{10}S_2$	465	leaves	70% methanol	[27, 45]
52	Glucoalyssin	$C_{13}H_{25}NO_{10}S_3$	452	leaves	70% methanol	[45]
53	Glucoiberin	$C_{11}H_{21}NO_{10}S_3$	424	leaves	70% methanol	[45]
54	4-Methoxyglucobrassicin	$C_{17}H_{22}N_2O_{10}S_2$	479	leaves	70% methanol	[45]
55	Glucoiberverin	$C_{11}H_{21}NO_9S_3$	408	leaves	70% methanol	[45]
56	Glucoerucin	$C_{12}H_{23}NO_9S_3$	422	leaves	70% methanol	[45]
57	Dihydrogluconapin	$C_{11}H_{21}NO_9S_2$	375	leaves	70% methanol	[45]
58	Glucoberteroin	$C_{13}H_{25}NO_9S_3$	436	leaves	90% methanol	[46]
59	Sinigrin	$C_{10}H_{17}NO_9S$	359	leaves	70% methanol	[47]
60	Glucocochlearin	$C_{11}H_{21}NO_9S_2$	375	roots	water	[48]
61	3-Butenyl isothiocyanate	C_5H_7NS	113	leaves, root, seeds	water	[49]
62	Butyl isothiocyanate	C_5H_9NS	115	leaves, root, seeds	water	[49]
63	4-Pentenyl isothiocyanate	C_6H_9NS	127	leaves, root, seeds	water	[49]
64	Heptyl isocyanate	$C_8H_{15}NS$	157	seeds, sprouts	ethanol	[43]
65	Isopropyl isothiocyanate	C_4H_7NS	101	seeds, sprouts	ethanol	[43]
66	Allyl thiocyanate	C_4H_5NS	99	seeds, sprouts	ethanol	[43]
67	Allyl isothiocyanate	C_4H_5NS	99	seeds,sprouts	ethanol	[43]
68	3-Methylbutyl isothiocyanate	$C_6H_{11}NS$	129	seeds,sprouts	ethanol	[43]
69	Pentyl isothiocyanate	$C_6H_{11}NS$	129	seeds,sprouts	ethanol	[43]
70	Hexyl Isothiocyanate	$C_7H_{13}NS$	143	seeds,sprouts	ethanol	[43]
71	4-Methylpentyl Isothiocyanate	$C_7H_{13}NS$	143	seeds,sprouts	ethanol	[43]
72	2-butyl isothiocyanate	C_5H_9NS	115	seeds,sprouts	ethanol	[43, 49]
73	Benzyl isothiocyanate	C_8H_7NS	149	roots	water	[50, 51]
74	Erucin	$C_6H_{11}NS_2$	161	leaves	water	[51]
75	Iberin	$C_5H_9NOS_2$	163	leaves	water	[51]
76	Goitrin	C_5H_7NOS	129	leaves	water	[51]
77	Berteroin	$C_7H_{13}NS_2$	175	leaves	70% methanol	[47]
78	Sulforaphane	$C_6H_{11}NOS_2$	177	leaves	70% methanol	[47]
79	2-Phenylethyl isothiocyanate	C_9H_9NS	163	leaves	70% methanol	[47, 52]

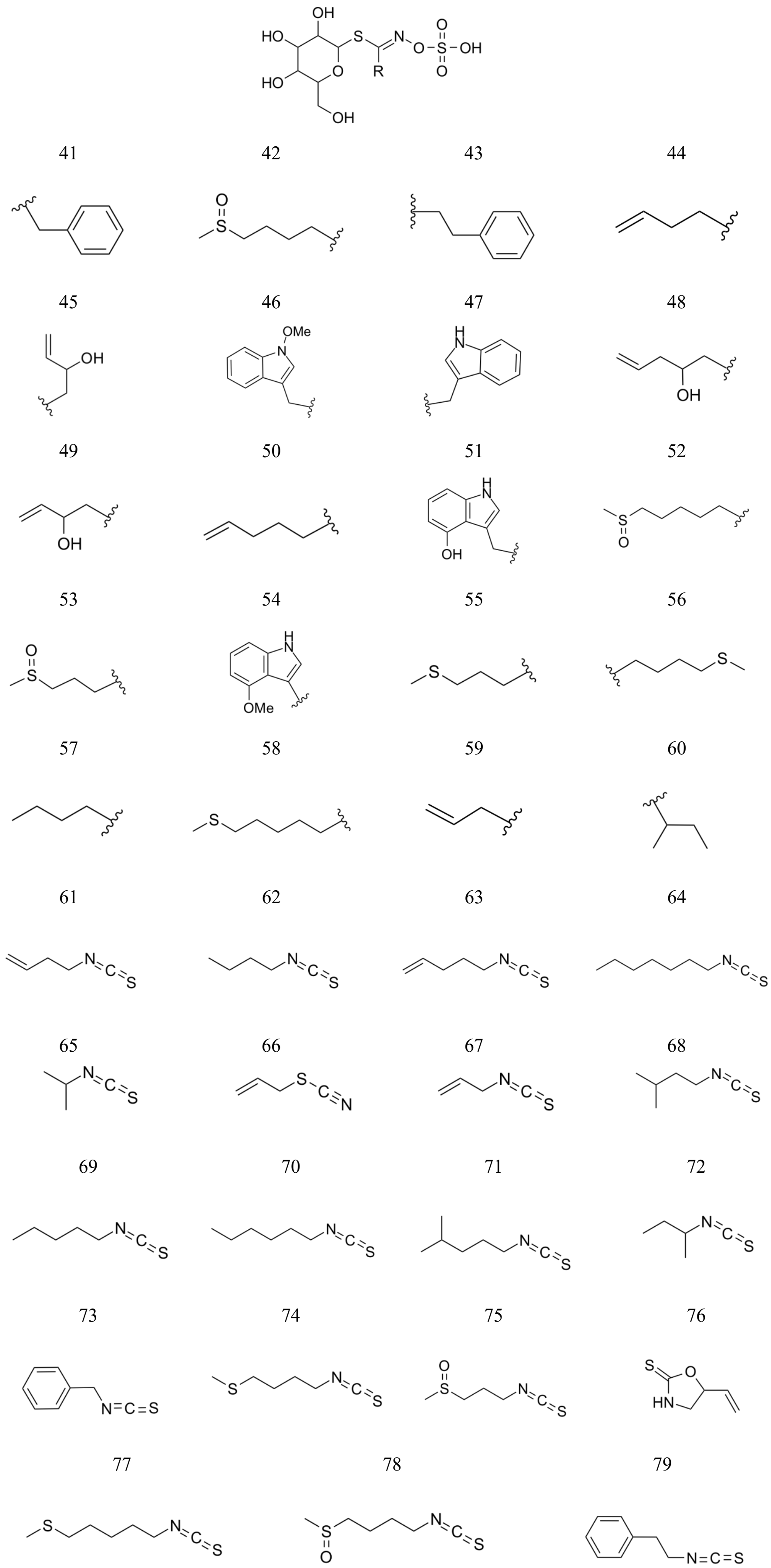


Figure 4 Chemical structure of glucosinolates and isothiocyanates in turnip.

buds (14%) has a content was significantly higher than that of aconitic acid in roots (2%)[31]. Organic acid components in turnip showed good antioxidant, anti-hypoxic and bacteriostatic effects, such as p-coumaric acid as the main active ingredient of turnip for anti-hypoxia[32]. Table 3 and Fig. 5 summarize the main organic acid components of turnip.

Table 3 Organic acids in turnip

No.	Component	Molecular	MW (g/mol)	Resources	Solvents	Reference
80	Shikimic acid	$C_7H_{10}O_5$	174	leaves, stems, flower buds, roots	water	[31]
81	Aconitic acid	$C_6H_6O_6$	174	leaves, stems, flower buds, roots	water	[31]
82	Fumaric acid	$C_4H_4O_4$	116	leaves, stems, flower buds, roots	water	[31]
83	Citric acid	$C_6H_8O_7$	192	leaves, stems, flower buds, roots	water	[31]
84	Ketoglutaric	$C_5H_6O_5$	146	leaves, stems, flower buds, roots	water	[31]
85	Oxalic acid	$C_2H_2O_4$	90	leaves	water	[53]
86	Ascorbic acid	$C_6H_8O_6$	176	leaves	water	[52]
87	Malic acid	$C_4H_6O_5$	134	leaves, stems, flower buds, roots	water	[31]
88	Succinic acid	$C_4H_6O_4$	118	leaves, stems, flower buds, roots	water	[31]
89	Glutamic acid	$C_5H_9NO_4$	147	leaves, stems, flower buds, roots	water	[31]
90	Syringin	$C_{17}H_{24}O_9$	372	roots	95% ethanol	[54]
91	Triandrin	$C_{15}H_{20}O_7$	312	roots	95% ethanol	[54]
92	5-Hydroxyferuloyl malate	$C_{14}H_{14}O_9$	326	leaves	50% methanol	[55]
93	4-Hydroxy-benzoate glucoside	$C_{13}H_{16}O_8$	300	roots	ethanol	[56]
94	Trans-ferulic glucoside	$C_{17}H_{22}O_8$	354	roots	ethanol	[56]
95	Ferulic acid	$C_{10}H_{10}O_4$	194	roots	ethanol	[56]
96	Sinapic acid	$C_{11}H_{12}O_5$	224	leaves	70% methanol	[27]
97	3-*p*-coumaroylquinic acid	$C_{16}H_{18}O_8$	338	leaves	70% methanol	[27]
98	Caffeic acid	$C_9H_8O_4$	180	leaves	70% methanol	[27]
99	*p*-coumaric acid	$C_9H_8O_3$	164	leaves	70% methanol	[27]

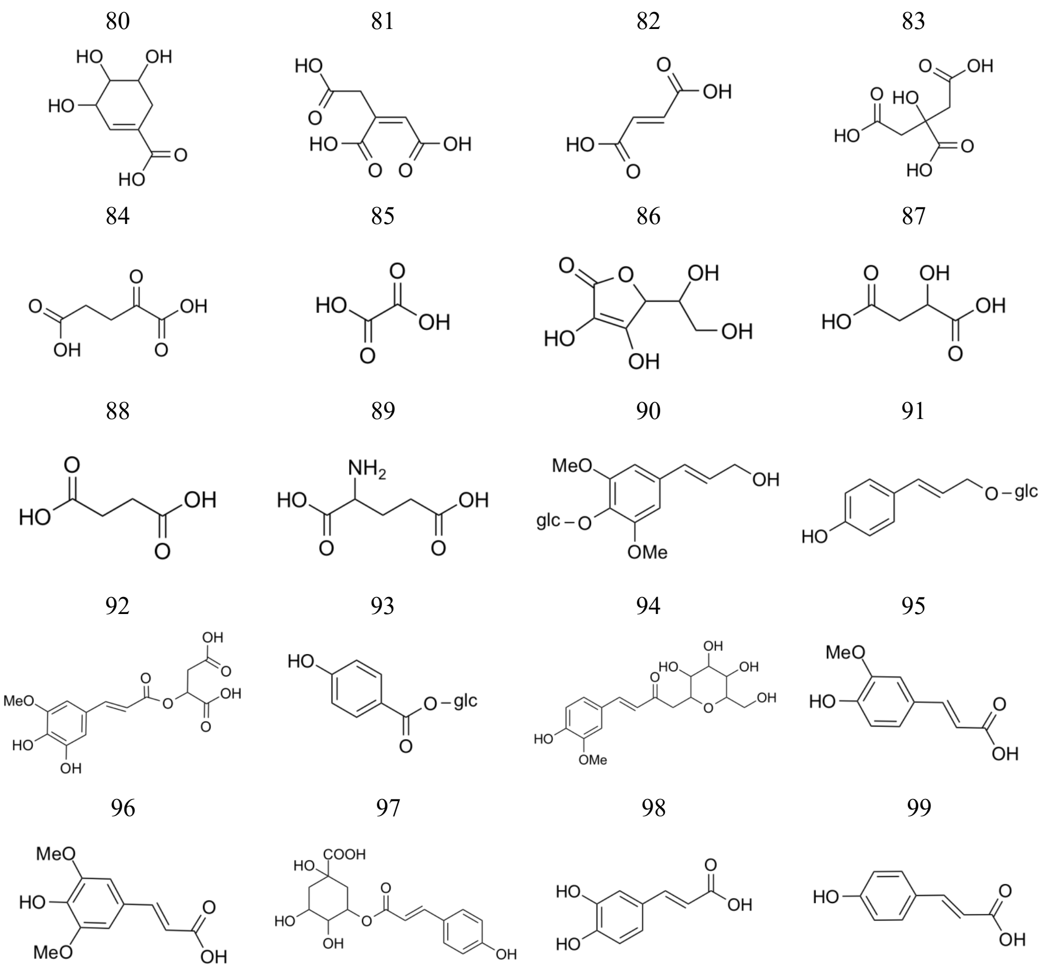


Figure 5 Chemical structure of organic acids in turnip.

5.5 Others

In addition to the above compounds, turnip also contains triterpenes (100-102)[30,36] and indoles (103–110)[12]. Taveira *et al.* detected a total of alcohols, aldehydes, esters, and enol terpenes in turnip leaves using headspace solid-phase microextraction (HS-SPME) in conjunction with gas chromatography-ion trap mass spectrometry (GC/IT-MS)[43]. Table 4 and Fig. 6 demonstrate the main other classes of turnip components.

6 Pharmacology

6.1 Anti-cancer activity

Cruciferous plants are a rich source of glucosinolates and their hydrolyzed products, and epidemiological studies have shown that human consumption of cruciferous foods reduces the risk of certain cancers[61,62]. Hong *et al.* detected that β-phenylethyl isothiocyanate, an isothiocyanate found in high levels in turnip, had a concentration-dependent inhibitory effect on the growth of the human hepatocellular carcinoma cell line HepG2, with an IC_{50} value of 24.5 μM[52]. Another study also showed that phenethyl isothiocyanate derived from cruciferous plants could inhibit the activation of the JAK-STAT3 signaling cascade reaction in prostate cancer cells, thus exerting anticancer activity[27].

Macrophages are very important immune cells in the human body, and under the influence of the tumor cell environment, macrophages differentiate into different types of tumor-associated macrophages (TAMs), which are mainly classified into M1-type and M2-type, and the process of differentiation between the two types is known as polarization. M1-type cells promote inflammatory responses and kill intracellular infected pathogens, which can play an anti-cancer activity. On the contrary, M2-type cells produce anti-inflammatory factors that can promote tumor development[63,64]. In recent years, studies on turnip polysaccharides have been developed[65]. Guo explored the antitumor activity of turnip *in vitro* and *in vivo* by using macrophage polarization as a research object, and the results showed that turnip could promote the expression of M1-type cell-associated factors including inducible nitric oxide synthase (iNOS) and cyclo-oxygenase-2 (COX-2), and also inhibit the M2-type cell markers, Arg-1, CD206 and CD163 expression, thus causing M2-type cells and TAM to shift to M1-type, and the activation of STAT signaling pathway plays an important role in the cell polarization process[37]. Thus, it is known that turnip can inhibit tumor development by mediating macrophage polarization. It has also been shown that turnip polysaccharides can promote the growth of mouse monocyte macrophage leukemia cells (RAW264.7), stimulate their endocytosis/pinocytosis and the release of inflammatory cytokines such as NO, tumor necrosis factor (TNF), and interleukin-6 (IL-6), and at the same time, induce the release of reactive oxygen species (ROS) from A549 cells, which causes changes in mitochondrial membrane potential, and thus exerts an anti-lung cancer effect[10,66]. Halike concluded that turnip petroleum ether extracts can exert anticancer activity by inducing cell cycle blockade and apoptosis while activating immune function *in vivo*[67].

Cisplatin is a commonly used chemotherapeutic drug in the middle and late stages of cancer, but its side effects are large and its prognosis is poor. Researchers have long found that the therapeutic regimen of cisplatin in combination with polysaccharides can attenuate the adverse effects of cisplatin[68-70]. Kong *et al.* demonstrated that the natural active ingredient, turnip polysaccharides, can enhance the sensitivity of cisplatin chemotherapy and significantly enhance the *in vivo* tumor suppression of cisplatin, and the mechanistic study showed that turnip polysaccharides induce apoptosis of liver cancer cells by triggering the caspase reaction. Mechanistic studies showed that turnip polysaccharides induced apoptosis of hepatocellular carcinoma cells by triggering the caspase reaction and alleviated the adverse effects of cisplatin, such as weight loss and decreased immune function. This study also showed that turnip polysaccharides could be used as an adjuvant or dietary supplement to enhance the efficacy of cisplatin chemotherapy by maintaining a more effective intestinal microenvironmental homeostasis[11].

Another study pointed out that the endophytic fungi of medicinal plants have similar active components and pharmacological effects as their host drugs. Using turnip root fermentation, researchers extracted four strains of endophytic fungi and examined their in vitro anticancer activity, which, in combination with metabolomics results, indicated that these endophytic fungi and their breakdown products directly inhibited alveolar adenocarcinoma cell activity[9].

Table 4 Other components in turnip

No.	Component	Molecular	MW (g/mol)	Resources	Solvents	Reference
100	Ursolic Acid	$C_{30}H_{48}O_3$	457	seeds	95% ethanol	[30]
101	Oleanolic acid	$C_{30}H_{48}O_3$	457	seeds	95% ethanol	[30]
102	*β*-Sitosterol	$C_{29}H_{50}O$	415	seeds	95% ethanol	[30]
103	arvelexin	$C_{11}H_{10}N_2O$	186	roots	80% methanol	[57]
104	2-C-*β*-D-glucopyranosyl-1-methoxyindole-3-acetonitrile	$C_{11}H_{10}N_2O$	186	roots	95% ethanol	[58]
105	6-hydroxy-1-methylindole-3-acetonitrile	$C_{11}H_{10}N_2O$	186	roots	95% ethanol	[59-60]
106	3-Indoleacetonitrile	$C_{10}H_8N_2$	156	roots	70% ethanol	[36]
107	4-Methoxyindole-3-Acetonitrile	$C_{11}H_{10}N_2O$	186	roots	70% ethanol	[36]
108	Indole-3-carboxaldehyde	C_9H_7NO	145	roots	70% ethanol	[36]
109	Brassicaphenanthrene A	$C_{32}H_{40}O_4$	489	roots	95% ethanol	[60]
110	1,2-disinapoylgentiobioside	$C_{33}H_{40}O_{19}$	741	leaves	70% methanol	[27]
111	1-sinapoyl-2-feruloylgentiobioside	$C_{32}H_{38}O_{18}$	711	leaves	70% methanol	[27]
112	1,2,2′-trisinapoylgentiobioside	$C_{44}H_{50}O_{23}$	947	leaves	70% methanol	[27]
113	1,2′-disinapoyl-2-feruloylgentiobioside	$C_{33}H_{40}O_{19}$	741	leaves	70% methanol	[27]

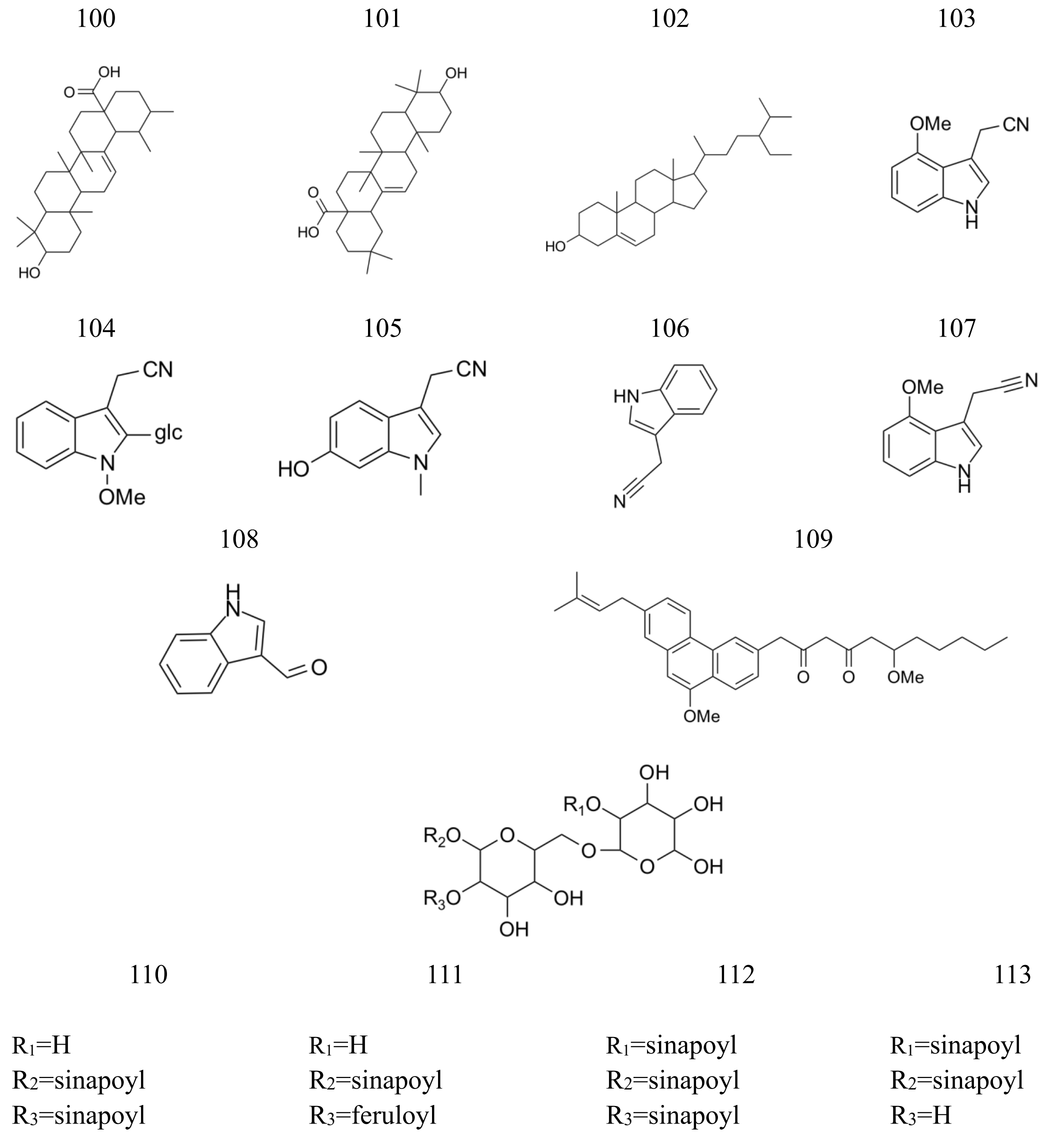


Figure 6 Chemical structure of others components in turnip.

6.2 Anti-hypoxic activity

Oxygen is an important source of life sustenance for most organisms. Prolonged exposure to the low oxygen environment at high altitude is detrimental to human health and can lead to problems such as abnormal cardiopulmonary function[71,72]. Under normal conditions, glutamate reductase (GR) in the body reduces oxidized glutathione (GSSG) to glutathione (GSH) using reduced coenzyme II (NADPH) as a substrate, and the main role of GSH is antioxidant. However, under hypoxic conditions, GR, glutathione peroxidase (GPx) activity is reduced, leading to a decrease in GSH levels[73]. Chu found that p-coumaric acid (CA) and p-coumaric acid-β-D-glucopyranoside (CAG) are the characteristic constituents of turnip to exert its anti-hypoxic effects[6]. Turnip extracts can produce anti-hypoxic effects by activating the PI3K/Akt pathway in a mouse hippocampal neuronal cell (HT-22 cell) model of oxygen glucose deprivation/reperfusion (OGD/R) injury[14]. When mice were gavaged with CA (100 mg/kg) for 4 consecutive days and then placed in a hypoxic environment (O_2 content of about 9.5%), the activities of GR and GPx were significantly elevated in the lung tissues of the hypoxic mice after CA gavage (by 8.82% and 60.38%, respectively, compared with that of the untreated group), which suggests that CA can restore the disruption of the glutathione system due to hypoxia, which is one of the pathways to ameliorate hypoxic pulmonary edema[7]. In addition, Xie examined the effects of polysaccharides isolated from the aqueous extract of turnip in a mouse model of normobaric hypoxia, acute cerebral ischemic hypoxia, and sodium nitrite chemical toxicity hypoxia, and the results indicated that turnip polysaccharides exhibited significant anti-hypoxic activity in all three hypoxia models[3]. It has been shown that the administration of turnip powder for 7 days (7.5 g/dose, 2 times/day) in healthy individuals helps to enhance the body's ability to tolerate hypoxia[6]. Therefore, this is expected to be used as an entry point for the development of a turnip anti-hypoxia drug.

6.3 Anti-oxidation activity

DPPH, ABTS radical scavenging assay, and reducing power assay are commonly used to examine the antioxidant capacity of substances[74,75]. A study by Wang evaluated the *in vitro* antioxidant capacity of turnip polysaccharides using DPPH, ABTS, hydroxyl radical scavenging assay, and the reducing power of polysaccharides, and the results indicated that the concentration of the crude extract was 4.0 mg/mL, and its scavenging rate of the DPPH, ABTS radicals, hydroxyl and radicals was 44.10%, 47.61%, and 84%, respectively, indicating that turnip polysaccharides have good antioxidant capacity[5]. A neutral polysaccharide isolated and purified from turnip polysaccharides by Cao *et al.* also showed significant antioxidant activity[76]. In addition, turnip oil also possessed high DPPH radical scavenging activity, scavenging 10%, 19%, and 31% of DPPH radicals after mixing with DPPH for 1, 30, and 60 min, respectively[12]. Fernandes examined the antioxidant activity of turnip leaves, stems, buds, and roots, respectively, and concluded that the best antioxidant activity was found in the bud portion of turnip, which mainly depends on the content of total phenols and organic acids[8].

Oxidative stress refers to an imbalance in the redox system of the human body, which can lead to the accumulation of ROS in the body, and too many reactive oxygen species can damage nerve cells, which can lead to neurological diseases[77,78]. The ethanolic extract of turnip can produce neuroprotective effects against H_2O_2-induced oxidative damage in rat adrenal chromaffin cells (PC12), which exerts antioxidant activity specifically by increasing the activities of SOD and GPx, reducing the production of malondialdehyde (MDA), LDH, and ROS, as well as attenuating the apoptosis of PC12 cells induced by H_2O_2[79]. In an OGD/R-induced HT-22 cell injury model, it was found that aqueous extract of turnip significantly enhanced cell viability and promoted cell proliferation, while inhibiting the levels of lactate dehydrogenase (LDH) and ROS, and enhancing the activities of endogenous antioxidant enzymes including superoxide dismutase (SOD), GPx and catalase (CAT). In addition, turnip extracts significantly inhibited apoptosis by increasing the total number of mitochondria, decreasing the levels of cleaved cysteinyl asparagin-3 and pro-apoptotic gene Bax, and increasing the activity of the B lymphoblastoma-2 gene (Bcl-2), which can be used to make a preliminary judgment that turnip enhances the antioxidant capacity of cells[14]. Gavage of CA (8 mg/kg) to mice for 7 consecutive days before inducing myocardial infarction, the final results showed that CA administration group could protect the heart of cardiac infarcted mice by regulating oxidative stress[80]. In conclusion, turnip has potential as an antioxidant of natural origin.

6.4 Hypoglycemic activity

Prolonged hyperglycemia can lead to a variety of complications, such as diabetic nephropathy, diabetic cardiovascular disease, and other serious health hazards for humans[81]. Type 2 diabetes mellitus is characterized by postprandial hyperglycemia, and α-glucosidase inhibitors reduce the decomposition of starchy polysaccharides into monosaccharides for hypoglycemic purposes[82]. This study reported for the first time the inhibitory activity of nine components extracted from turnip flowers on intestinal α-glucosidase with IC_{50} values ranging from 14.43–50.20 μM[83]. Cao *et al.* isolated and purified a neutral polysaccharide from turnip polysaccharides, which showed 44.62% inhibition of α-glucosidase activity at a concentration of 0.5 mg/mL without concentration dependence, and the results of *in vitro* bioactivity studies showed that it has good hypoglycemic activity[76]. In addition, the ethanol extract of turnip root also has hypoglycemic activity, which can promote glucose and lipid metabolism and inhibit the development of type 2 diabetes[84,85]. Hassanzadeh-Taheri established a rat model of tetracosane-induced diabetic nephropathy, and after gavage of the aqueous extracts of turnip leaves with different concentrations (200, 400 mg/(kg·day)) for 8 weeks, the diabetic nephropathy indexes of the rats showed a significant dose-dependent reduction such as fasting blood glucose level, urine output, urinary protein, urea nitrogen and plasma creatinine[86].

6.5 Neuroprotective activity

In a study, a phenanthrene derivative named Brassicaphenanthrene A was isolated from turnip root, which effectively blocked glutamate-induced oxidative neuronal cell death by activating the Nrf2/HO-1 signaling pathway in HT-22 cells[60]. Kurita *et al.* obtained from turnip 4'-O-β-D-glucopyranosyl-4-hydroxy-3,3',5-trimethoxychalcone, which was found to induce neurotumor cell cycle block at G1 phase, as well as tumor cell apoptosis via the caspase pathway, thus exerting a protective effect on neuroblastoma cells[87]. Another study established a mouse model of middle cerebral artery occlusion (MCAO), after turnip aqueous extract administration of mice brain atrophy volume reduction, 3 days after the administration of neuronal behavioral errors in the rate of reduction, combined with the results of the *in vitro* HT-22 cell study, indicating that the water extract of turnip could show neuroprotective effect on HT-22 cells by activating PI3K/Akt/mTOR pathway. Combining these two *in vitro* and *in vivo* studies, it is known that turnip may be related to anti-ischemic neuroprotection[14,88].

6.6 Immunomodulatory activity

To confirm the immunomodulatory effects of turnip, researchers examined the effects of turnip extract on RAW264.7 cells and showed that it significantly increased cell viability and inhibited macrophage transformation to pro-inflammatory M1-type cells[89]. Guo *et al.* investigated the effect of polysaccharides from turnip root on RAW264.7 macrophages and found that turnip polysaccharides significantly enhanced macrophage phagocytosis by activating the Akt/NF-κB signaling pathway and stimulated immune activity by up-regulating iNOS and TNF-α, pro-inflammatory cytokines. This study suggests that turnip polysaccharides can be used as an immune adjuvant for the treatment of inflammatory diseases and lays the foundation for further studies on their immunomodulatory mechanisms[65]. Alotaibi extracted and identified 57 chemical components from turnip flowers for the first time. The extract exerted immunomodulatory activity in lipopolysaccharide-stimulated peripheral blood mononuclear cells (PBMCs) by down-regulating the expression of COX-2, iNOS, IL-6, TNF-α and nuclear factor-κB (NF-κB)[90]. Delayed hypersensitivity (DTH) is an immune-inflammatory response. This study established a sheep erythrocyte-induced DTH rat model and examined the immunomodulatory effects of CA, which significantly suppressed the DTH response in the CA-treated group as compared to the untreated rats and was found to ameliorate the DTH by inhibiting leukocyte migration and activation, possibly through the down-regulation of lymphokine production and release[91].

6.7 Anti-bacterial and anti-inflammatory activity

Isothiocyanates have good antimicrobial activity, among which β-phenylethyl isothiocyanate has inhibitory activity against the *foodborne pathogen Vibrio parahaemolyticus* with a minimum inhibitory concentration (MIC) of 100 μg/ml. In addition to this ingredient has shown significant antibacterial activity against *Staphylococcus aureus* and *Bacillus cereus*[52]. *Helicobacter pylori* is a Gram-negative bacterium that causes gastritis and peptic ulcers when infected. The treatment of *Helicobacter pylori* is long term, the search for a natural active ingredient is necessary[92]. Aires examined the activity of different concentrations of 2-isothiocyanatophenethyl ester against microorganisms from the gastrointestinal tracts of both humans and animals and showed that the antimicrobial activity of 2-isothiocyanatophenethyl ester against Gram-positive bacteria had higher antibacterial activity than against Gram-negative bacteria in a dose-dependent manner[93]. In addition, organic acid compounds contained in turnips also showed dose-dependent antibacterial activity against Gram-positive bacteria[32]. In an animal study, black mustard enzyme from turnip was shown to inhibit *H. pylori*, and in the high dose group (200 mg/(kg·day)) black mustard enzyme had an inhibitory activity comparable to that of amoxicillin, which inhibited *H. pylori* colonization while attenuating the infiltration of inflammatory cells and enhancing the immune response against the bacteria[94].

The active ingredient of turnip had a significant effect on the expression levels of inflammation-related proteins Bax, Bcl-2, and cysteinyl asparaginase-3[14]. In a study, a mouse model of arthritis was established, and CA administration resulted in reduced paw edema and decreased levels of lysosomal enzymes, glycoproteins, and tissue labeling enzymes, which confirmed the anti-inflammatory effect of CA on adjuvant-induced arthritis. CA also showed significant anti-inflammatory effects in steroid-induced arthritis rats by decreasing the expression of inflammatory mediator, TNF-α, and circulating immune complexes[90, 95].

6.8 Bone-forming activity

Jeong *et al.* characterized the ethanolic extract of turnip root using ultra performance liquid chromatography-mass spectrometry (UPLC-MS) and identified a total of 13 glucosinolates and found that this extract significantly increased alkaline phosphatase (ALP) activity, collagen synthesis, and mineralization levels in human osteoblast-like MG-63 cells, as well as increasing serum osteocalcin production, improving bone microstructure, and having a positive effect[96]. A study found that turnip oil may also have a therapeutic effect on osteoporosis. Turnip oil is rich in monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA), which play a vital role in bone metabolism. Both of them can up-regulate the expression of osteoblast-specific genes. The experimental results show that turnip oil can increase the levels of calcium, phosphorus, bone alkaline phosphatase and vitamin D in osteoporotic rats, thereby improving bone loss and promoting bone growth[12, 97].

6.9 Others

Turnip polysaccharide has a regulatory effect on intestinal flora. *In vitro* studies showed that turnip polysaccharide did not degrade when fermented in simulated gastrointestinal fluid, but the abundance of *lactic acid bacteria*, *bifidobacteria*, and *chain bacteria* increased after fermentation by intestinal flora. These data indicate that turnip polysaccharide can play a prebiotic role by regulating intestinal flora, promote the metabolism of amino acids and carbohydrates, and maintain gastrointestinal health[98].

Hua *et al.* noted that the body becomes immunosuppressed after strenuous exercise and the body is left in a state of fatigue[99, 100]. A metabolomics analysis concluded that turnip extract inhibited exercise fatigue in mice mainly through linoleic acid metabolism, ketone body production and degradation, taurine and taurine metabolism, nicotinic acid salt and nicotinamide metabolism[90, 101].

7 Toxicology and pharmacokinetics

Chu determined the effects of 0–250 μg/mL turnip n-butanol phase, n-butanol-ethyl acetate phase, aqueous phase, and 0–10 μg/mL turnip polysaccharides on the cellular activity of pheochromocytoma (dPC12) in hyperdifferentiated rats, and none of the above fractions were found to have significant cytotoxicity[56]. 4-Methylsulfinylbutyl glucosinolate is a typical representative of aliphatic glucosinolates, also known as sulforaphane. Sulforaphane can be obtained by hydrolysis of sulforaphane, which is one of the isothiocyanates[44]. In humans, isothiocyanates are metabolized via the mercapturic acid pathway. Administration of 16 mmol (low dose) or 52 mmol (high dose) of radicicolothionein resulted in plasma concentrations that reached a maximum at 1.5 h and 2 h, respectively, after administration, with plasma concentrations approaching baseline at 24 h. The area under the concentration curve (AUC) and the maximum concentration (C_{max}) in plasma were dose-dependent. The C_{max} of low-dose and high-dose were 2.2–0.8 mM and 7.3–2.9 mM, respectively[102]. Healthy subjects received a single dose equivalent to an extract containing 111 mmol of glucosinolates or isothiocyanates, and their cumulative metabolite urinary dithiocarbamate excretion was 88.9–5.5 mmol, linear in the dose range of 25–200 mmol, and first-order kinetics[44, 103].

8 Conclusion and future perspectives

In this paper, the traditional use, botany, phytochemistry, pharmacology and other related contents of turnip were reviewed. A total of 113 components of turnip were summarized, including flavonoids, glucosinolates and their decomposition products, organic acids and other compounds. Turnip has rich pharmacological activities, including anti-cancer, anti-hypoxia, anti-oxidation, hypoglycemic, neuroprotective, immunomodulatory, anti-inflammatory and anti-bacterial, and promoting bone growth. In recent years, the research of turnip mainly focuses on its agricultural cultivation, such as cross breeding[104], pest control[105], increasing yield[106], etc. However, the medicinal research is not sufficient, and its basic research, such as the extraction and separation of chemical components, is still being explored.

First of all, the medicinal method of turnip has been recorded for the first time in the ancient Chinese book "*Famous Doctor Biography*" 1,700 years ago. Therefore, its application in pharmacy can be actively explored and developed. At present, the medicinal research of turnip focuses on the extraction and separation of chemical components and the pharmacological activity of crude extracts, and there is a lack of related research on single active components. In the future, we should continue to explore the extraction and separation methods of various components of turnip, improve the extraction rate, and provide a more solid foundation for the study of single components. Secondly, most of the studies on the pharmacological activity of turnip are animal experiments or in vitro studies, lacking sufficient clinical trial data. Therefore, future studies should carry out systematic clinical trials on compounds with sufficient basic research of turnip. Thirdly, there are many pharmacological effects of turnip, but the mechanism of action is not clear, and there is a lack of pharmacokinetic and toxicological studies. In order to ensure the safety of its medication, the pharmacokinetic and toxicological studies of turnip should be carried out, and the mechanism of action should be systematically explored through more pharmacological experiments and genomics, which will help turnip from food to medicine. Fourthly, the chemical composition of turnip is complex and diverse. In order to ensure its quality is stable and controllable, a set of standard quality evaluation systems should be established and improved, such as establishing an internationally unified identification method, content determination method, and establishing a standard fingerprint. Fifth, turnip has a long history of dual use of medicine and food, and is widely consumed in the plateau area. Both ancient medical books and modern studies have shown that it has anti-hypoxia activity. Using this point, drugs with related functions can be developed to prevent and improve symptoms such as altitude sickness. The hypoglycemic and anticancer effects of turnip are also significant. On the basis of previous studies, we can continue to explore the deeper mechanism of action and strive to develop clinical drugs as soon as possible. Sixth, in the history of medicinal and edible use of turnip, the utilization rate of roots is the highest, followed by leaves and seeds. Modern research also focuses on the fleshy roots of turnip. Subsequent research can be extended to other parts of the turnip, and strive for the whole plant application of this medicinal plant. Finally, in addition to paying attention to the medicinal value of turnip, its application in food can also be explored.

This paper reviews the traditional use, botany, phytochemistry, pharmacology and other related research of turnip. With the improvement of consumers' attention to health, they are more inclined to choose natural active ingredients with health benefits. Modern medicine is also committed to finding such ingredients. Turnip, as a long-standing medicinal and edible medicinal material, has great potential. In the future, it can be innovated in drugs, adjuvant treatment drugs and functional food development (Fig. 7).

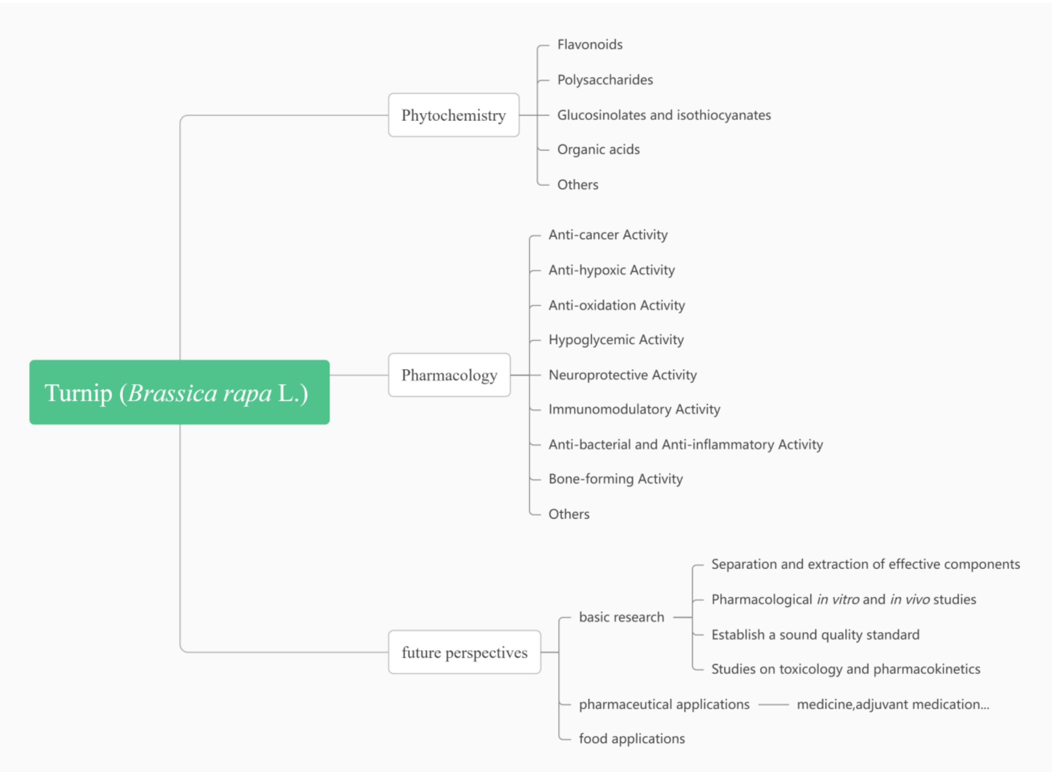


Figure 7 A brief overview of turnip ingredients, pharmacology and future prospects.

Conflicts of interest

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

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