Review Article
Food Science and Technology

ISSN 0101-2061 (Print)
ISSN 1678-457X (Online)

DOI: https://doi.org/10.1590/fst.72722

Chemical constituents and bioactivities of Rosa roxburghii: a systematic review

Jianmei WANG[1], Guopan WANG[1], Xianting WANG[1], Lin QIN[1], Chong XU[2], Xiangqian SHE[3], Yuqi HE[1]*, Daopeng TAN[1]*

Abstract

Rosa roxbughii Tratt (RRT) is a welcome medicinal and edible fruit with unique functions and nutrients in China. In the past decades, extensive research including chemical constituents and bioactivities of RRT were reported. A total of small 78 small molecules, such as flavonoids, organic acid, triterpenes, etc. and 11 polysaccharides have been isolated from RRT. Its antioxidant, anti-tumor and other pharmacological effects were also discovered. This paper reviews the progress of those information for the R&D of RRT in the future.

Keywords: *Rosa roxburghii* Tratt; chemical constituents; biological activities.

Practical Application: The review provides a comprehensive information for consumers and researchers to understand RRT Chemical constituents and bioactivities.

1 Introduction

In recent years, the research and development of functional fruit juice or beverage products made from fruits and vegetables has attracted increasing attention (Coronado-Reyes et al., 2022; Köten & Ünsal, 2022; Ruiz-Cisneros et al., 2022; Yin et al., 2022). *Rosa roxbughii* Tratt (RRT) is a perennial deciduous tufted shrub of the genus Rosa in the rose family. RRT is an important fruit in China due to its nutritional and medicinal values (Wang et al., 2021). The traditional efficacy of this plant was described as early as in the book "Compendium of Materia Medica" in the Ming Dynasty, and it is believed that RRT has the efficacy of eliminating food and strengthening the spleen, astringent, and stopping diarrhea, mainly used for treating accumulated food and bloating, diarrhea and pain. RRT fruits are rich in nutrients, including sugars, organic acids, proteins, amino acids, fatty acids, vitamins and inorganic salts, especially vitamin C, which is much higher than other fruits and vegetables, and is known as the "King of Vitamin C" (Kuhn et al., 2018). Moreover, RRT fruit exhibits a marked extent of functional activities against aging (Luo et al., 2002; Ma et al., 1997), anti-tumor, atherosclerosis (Jian et al., 2015b; Zhang et al., 2001), reduce blood lipid and blood sugar (Chen et al., 2019b), and can also control intestinal flora disorders caused by diabetes (Wang et al., 2020). In order to offer a more comprehensive understanding of RRT and to conduct more in-depth research on their edible and medicinal values, this paper reviews the progress of research on its chemical constituents and biological activities.

2 Chemical constituents

The phytochemical constituents in edible plants play a vital role in human health. Previous phytochemical composition investigation has found that RRT in addition to rich containing vitamin C, also contains flavonoids, triterpenes, organic acids, tannins, polysaccharides and other chemical components. Their structures and names are listed below.

2.1 Flavonoids

Flavonoids are omnipresent natural products in the plant kingdom, having comprehensive biological activities including anti-free radical, anti-oxidative, anti-inflammatory, anti-microbial, anti-cancer and anti-glycating activities. RRT is rich in flavonoids, which are the primary active substances. To date, a total of 24 flavonoids (1-24) have been isolated from RRT (Table 1). Their structures are presented in Figure 1.

2.2 Triterpenes

Triterpenes are a cluster of polymers that possess isoprene as the basic unit, and are existed in vegetables, fruits and whole-wheat foods. Triterpenes are other core active constituents in RRT fruit with α-glucosidase inhibitory activity. 21 triterpenes were reported in RRT dominated by pentacyclic triterpenes. The triterpenes present RRT are summarised in Table 2. Their structure is shown in Figure 2.

2.3 Organic acids

Organic acids are not only delicious substances but also crucial medicinal ingredients in fruits that can boost digestion and sustain the acid-base balance in the human body. The composition and content of accumulated organic acids vary highly in diverse

Received 20 June, 2022
Accepted 01 Aug., 2022
[1] *Guizhou Engineering Research Center of Industrial Key-technology for Dendrobium Nobile, School of Pharmacy, Zunyi Medical University, Zunyi, China*
[2] *Institute of Traditional Chinese Medicine Preparation, Chongqing Traditional Chinese Medicine Hospital, Chongqing Academy of Traditional Chinese Medicine, Chongqing, China*
[3] *Guizhou Keytrum Bio-Tech Co. Ltd., Guiyang, China*
*Corresponding author: 1474755772@qq.com; yqhe.pharm@foxmail.com

Table 1. Flavonoids isolated from RRT (1-24).

No.	Compound name	Formula	Molecular weight (g/mol)	Part of plant	Ref.
1	Myricetin	$C_{15}H_{10}O_8$	318.24	Fruit	Hou et al., 2020; Wang et al., 2013; Zhang, 2005
2	Quercetin	$C_{15}H_{10}O_7$	302.24	Fruit	Hao et al., 2018; Hou et al., 2020; Porter et al., 2012; Wang et al., 2013; Wang et al., 2014; Xie et al., 2017; Zhang, 2005
3	Dihydroapigenin	$C_{15}H_{12}O_5$	273.07	Fruit	Liu et al., 2016
4	Kaempferol	$C_{15}H_{10}O_6$	286.24	Fruit	Zhang et al., 2017; Zhang, 2005
5	Luteolin	$C_{15}H_{10}O_6$	286.24	Fruit	Liu et al., 2016
6	Isoquercitrin	$C_{21}H_{20}O_{12}$	464.38	Fruit	Liu et al., 2016
7	Quercitrin	$C_{21}H_{20}O_{11}$	448.38	Fruit	Liu et al., 2016
8	Quercetin-3-O-xyloside	$C_{20}H_{18}O_{11}$	434.35	Fruit	Liu et al., 2016
9	Quercetin-3-O-rutinoside	$C_{27}H_{30}O_{16}$	610.51	Fruit	Yu et al., 2020
10	Quercetin-3-O-rhamnoside	$C_{21}H_{20}O_{11}$	448.38	Fruit	Yu et al., 2020
11	Quercetin-3-O-glucoside	$C_{21}H_{20}O_{12}$	464.37	Fruit	Yu et al., 2020
12	Rutin	$C_{27}H_{34}O_{16}$	614.55	Fruit	Tian et al., 2009a; Wang et al., 2014; Yang et al., 2019
13	Quercetin-3-O-D-xyloside	$C_{20}H_{18}O_{11}$	434.35	Fruit	Liu et al., 2016
14	Quercetin 3-O-[(6-O-3-hydroxy-3-methylglutaryl)-β-glucoside]	$C_{27}H_{29}NO_{16}$	623.52	Fruit	Liu et al., 2016
15	Kaempferol 3-O-[(X-O-3-hydroxy-3-methylglutaryl)-β-galactoside]	$C_{27}H_{28}O_{15}$	592.50	Fruit	Liu et al., 2016
16	Kaempferol 3-O-[(3-hydroxy-3-methylglutaryl)-β-glucuronide]	$C_{33}H_{34}O_{22}$	782.61	Fruit	Liu et al., 2016
17	Catechin	$C_{15}H_{14}O_6$	290.28	Fruit	Hao et al., 2018; Hou et al., 2020; Liang et al., 2001; Liu et al., 2016; Xie et al., 2017
18	Epicatechin	$C_{15}H_{14}O_6$	290.27	Fruit	Zeng, 2017
19	Epigallocatechin	$C_{15}H_{14}O_7$	306.27	Fruit	Liu et al., 2016
20	Icariin I	$C_{27}H_{30}O_{11}$	530.53	Seed	Ding et al., 2020
21	Protocentaurea B4	$C_{21}H_{18}O_9$	414.37	Seed	Ding et al., 2020
22	Epicatechin-5-O-β-D-glucopyranoside	$C_{21}H_{24}O_{11}$	452.41	Seed	Ding et al., 2020
23	Gallocatechin	$C_{15}H_{14}O_7$	306.27	Fruit	Yang et al., 2020
24	Phloridzin	$C_{21}H_{24}O_{10}$	436.41	Fruit	Liu et al., 2016

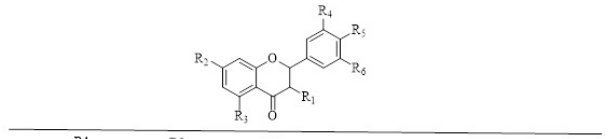
fruits. RRT fruits involve a certain percentage of organic acids, especially its ascorbic acid (Vitamin C, ~1300 mg) content is higher than most common fruits, such as tomato (~20 mg), strawberry (~50 mg), and kiwifruit (~100 mg). In addition to ascorbic acid, RRT also contains many other organic acids, such as lactic acid, malic acid, citric acid, succinic acid, oxalic acid, tartaric acid, etc. In Table 3, the Organic acids in RRT are summarized. Their structures are presented in Figure 3.

2.4 Tannins

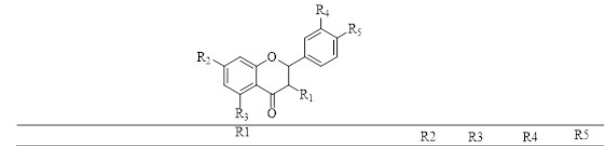
Tannins are the main component of unripe fruits with an astringent taste. RRT also contains a large number of tannins, mainly condensed tannins with proanthocyanidins as the basic unit. Tannins have a variety of biological activities, including antioxidant and anti-inflammatory effects, and prevention of neurological, cardiovascular and chronic intestinal disease function (Westfall & Pasinetti, 2019). Up to date, about 13 kinds of tannins have been found in RRT. The composition and structure are shown in Table 4 and Figure 4.

2.5 Polysaccharides

Polysaccharides are a group of sugars with complex and large molecular structures, formed by the condensation and water loss of several monosaccharide molecules. Polysaccharides are the most abundant biopolymers in nature and are widely distributed in plants, animals, microorganisms and other living organisms. Plant polysaccharides have become the focus of recent research in medical and food functional chemistry. RRT polysaccharides have been reported to increase gastrointestinal health and immune function and have potential applications as functional beverages



	R1	R2	R3	R4	R5	R6
1	OH	OH	OH	OH	OH	OH
2	OH	OH	OH	H	OH	OH
3	H	OH	OH	H	OH	H
4	OH	OH	OH	H	OH	H
5	H	OH	OH	H	OH	OH
6	Glu	OH	OH	H	OH	OH
7	Rha	OH	OH	H	OH	OH
8	Xyl	OH	OH	H	OH	OH
9	Rut	OH	OH	H	OH	OH
10	Rha	OH	OH	H	OH	OH
11	Glu	OH	OH	OH	OH	H
12	Rut	OH	OH	H	OH	OH
13	Xyl	OH	OH	H	OH	OH



R1		R2	R3	R4	R5
14	(6-O-3-hydroxy-3-methylglutaryl)-β-glucoside	OH	OH	OH	OH
15	(X-O-3-hydroxy-3-methylglutaryl)-β-galactoside	OH	OH	OH	OH
16	(3-hydroxy-3-methylglutaryl)-β-glucuronide	OH	OH	H	OH

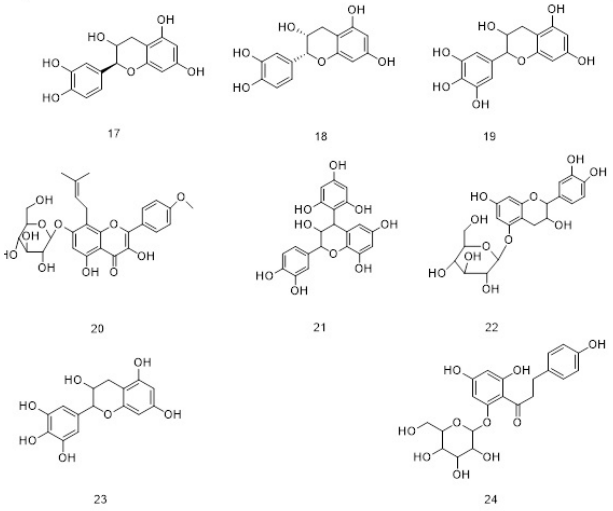


Figure 1. Chemical structures of Flavonoids isolated from RRT.

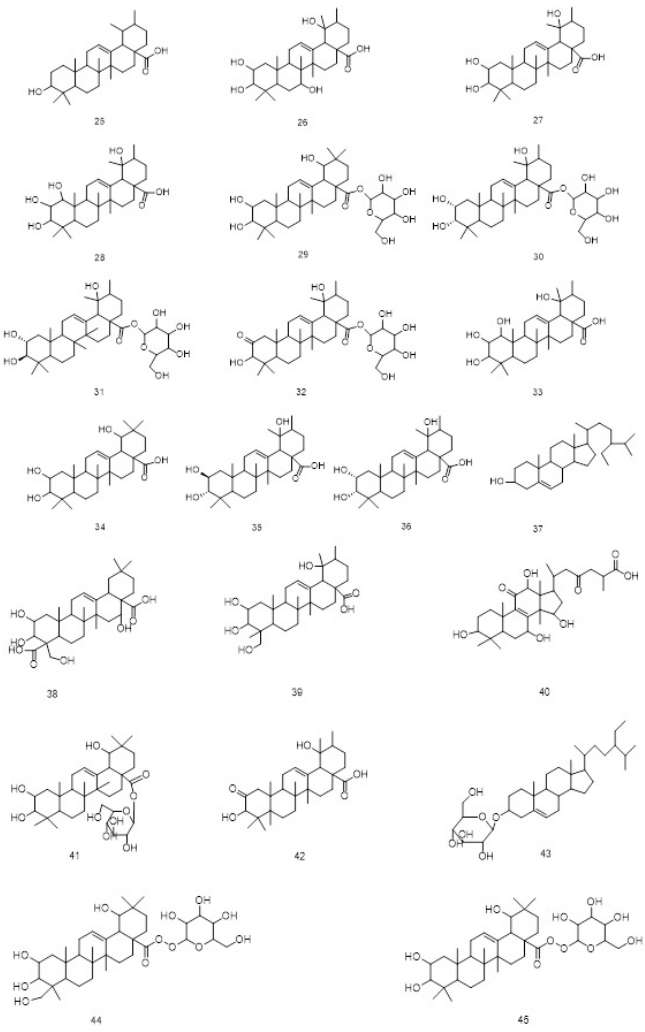


Figure 2. Chemical structures of Triterpenes reported in RRT (25-45).

and foods. The monosaccharide composition and preparation method of Rosa roxburghii polysaccharide are shown in Table 5.

3 Bioactivities

3.1 Anti-tumour properties

Several kinds of literature have reported that RRT has antitumor activity. Huang et al. (2013) found that RRT has an anti-tumor effect in vitro, which may be related to down-regulating the expression of Bad mRNA and inducing the differentiation of tumor cells, but not related to apoptosis and cell proliferation cycle arrest (Huang et al., 2013). Yang et al. (2020) used MCF-7, MDA-MB-468 hominine breast cancer cells and HCT116 human colon cancer cells to research the anti-proliferative effect of an ethanol-water extract of RRT fruit (Yang et al., 2020). RRT inhibits the growth of gastric cancer SGC-7901 cells in vitro, but has no significant effect on the proliferation and differentiation of human cord blood CD34 (Xu et al., 2006) hematopoietic stem cells (Liu et al., 2006). Dai et al. by using the MTT reduction test to determine the cytotoxicity of RRT on gastric cancer SGC-7901 and MKN-45 cells. The results showed that the extract of RRT had a certain inhibitory effect on the growth of gastric cancer SGC-7901 and MKN-45 cells in vitro in a dose-dependent and time-dependent manner, which indicated that RRT extract had a certain antitumor effect in vitro (Dai et al., 2005). Liu et al. (2012) Combined the use of extracts from RRT and Fagopyrum cymosum, the proliferation and apoptosis of three cancer cell lines (human esophageal squamous cell carcinoma CaEs-17, human gastric cancer SGC-7901 and lung cancer A549) were evaluated

Table 2. Triterpenes isolated from RRT (25-45).

No.	Compound name	Formula	Molecular weight (g/mol)	Part of plant	Ref.
25	Ursolic acid	$C_{30}H_{48}O_3$	456.71	Fruit	Dai et al., 2018
26	Roxburic acid	$C_{30}H_{48}O_6$	504.70	Fruit	Liang, 1987
27	Euscaphic acid	$C_{30}H_{48}O_5$	488.70	Fruit	Dai et al., 2015; Li et al., 2016a; Li et al., 2016c; Liang et al., 2019a; Liu & Yuan, 2021
28	1α,2β,3β,19α-tetrahydroxyurs-12-en-28-oic acid	$C_{30}H_{48}O_6$	504.71	Fruit	Fu et al., 2020; Liang et al., 2019a
29	2α,3α,19α-trihydroxy-olean-12-en-28-oicacid28-O-β-D-glucopyranoside	$C_{36}H_{58}O_{10}$	650.85	Fruit	Fu et al., 2020; Liang et al., 2019a
30	Kaiiichigoside F1	$C_{36}H_{58}O_{10}$	650.85	Fruit, Leaf	Dai et al., 2015; Fu et al., 2020; Li et al., 2016a; Li et al., 2016b; Liang et al., 2019a; Tian et al., 2009b
31	Rosamultin	$C_{36}H_{58}O_{10}$	650.85	Fruit, Leaf	Dai et al., 2015; Li et al., 2016a; Liang et al., 2019a; Tian et al., 2009b
32	Potentilanoside B	$C_{36}H_{56}O_{10}$	648.83	Fruit	Fu et al., 2020; Liang et al., 2019a
33	1β-hydroxyeuscaphic acid	$C_{30}H_{48}O_6$	504.71	Fruit	Dai et al., 2015; Li et al., 2016a; Li et al., 2016c
34	Arjunic acid	$C_{30}H_{48}O_5$	488.71	Fruit	Li et al., 2016a
35	Tormentic acid	$C_{30}H_{48}O_5$	488.71	Fruit	Li et al., 2016a
36	Euscaphic acid	$C_{30}H_{48}O_5$	488.71	Fruit	Liang, 1986
37	β-Sitosterol	$C_{29}H_{50}O$	414.70	Leaf	Tian et al., 2009b
38	Platyconic acid A	$C_{30}H_{46}O_8$	534.69	Seed	Ding et al., 2020
39	24-Hydroxytormentic acid	$C_{30}H_{48}O_6$	504.71	Seed	Ding et al., 2020
40	Ganoderic Acid C2	$C_{30}H_{46}O_8$	534.69	Seed	Ding et al., 2020
41	Arjunetin	$C_{36}H_{58}O_{10}$	650.85	Fruit	Dai et al., 2015; Li et al., 2016a; Singh et al., 2004
42	2-oxo pomolic acid	$C_{31}H_{48}O_5$	500.72	Fruit	Li et al., 2016a
43	β-Daucosterol	$C_{35}H_{60}O_6$	576.86	Leaf	Tian et al., 2009b
44	2α,3α,19α,24-tetrahydroxyolean-12-en-28-oic-acid 28-O-β-D-glucopyranosyl ester	$C_{36}H_{58}O_{12}$	682.85	Fruit	Li et al., 2016a
45	2α,3α,19α -trihydroxy-olean-12-en-28-oic acid 28-O-β-D-glucopyranoside	$C_{36}H_{58}O_{11}$	666.85	Fruit	Li et al., 2016a

by MTT assay and flow cytometry respectively. We found that the mRNA and protein expression levels of Ki-67 and Bcl-2 were greatly reduced, while the expression of Bax was significantly increased (Liu et al., 2012). Moreover, Chen et al. (2015) firstly discovered that RRT polysaccharides can effectively reduce the wound closure rate of A2780 cells. In addition, RRT could hinder the migration and infestation of ovarian cancer cells by decreasing MMP-9 expression (Chen et al., 2015). According to reports in the literature, RRT juice can obviously inhibit the proliferation of human leukemia K562 cells, and it can act at low concentrations, with the highest inhibition rate of 83.4% (Qiang et al., 2000). According to related reports, RRT juice can induce apoptosis of COC2 cells and inhibit the growth and proliferation of COC2 cells (Xu et al., 2006). Besides, flavonoids from RRT can play an important role in curbing autophagy by down-regulating the assay of LC3-II and up-regulating that of P62 (Yuan et al., 2020).

3.2 Antioxidant properties

More and more literature have been reported, that RRT polysaccharide has obvious antioxidant activity. In vitro antioxidant test showed that RRTP1-1 had the activity of scavenging free radicals against DPPH, hydroxyl and superoxide radicals. Antioxidant assays in vivo showed that RRTP1-1 could significantly enhance the activities of antioxidant enzymes (CAT, SOD, and GSH-Px), increase TAOC values, and reduce the LPO and MDA levels in the serum of D-Gal aging-induced mice. It is speculated that RRTP1-1 may be a new source of natural antioxidants for functional foods and dietary supplements (Chen & Kan, 2018a). According to reports RRTP can markedly improve the SOD, GSH-Px and CAT activities, and TAOC to some degree, and shorten the level of MDA in both serum and liver of D-Gal aging-induced mice (Chen & Kan, 2018b).

RRT polyphenol also has obvious antioxidant activity. Wang detected the antioxidant activity of 80% ethanol extract of RRT in vitro. The results showed that polyphenols might be the main antioxidant component in RRT. And ethyl acetate has the strongest activity (Wang, 2018). In addition, the free phenolic fraction and bound phenolic fraction were extracted from RRT pomace by solvent extraction method and alkaline hydrolysis method, separately. The results showed that RRT pomace could be a great and inexpensive source of natural antioxidants (Huang et al.,

Table 3. Phenolic acids isolated from RRT (46-65).

No.	Compound name	Formula	Molecular weight (g/mol)	Part of plant	Ref.
46	Ascorbic acid	$C_6H_8O_6$	178.14	Fruit	An et al., 2011; Hou et al., 2020; Liu et al., 2016; Wang & An, 2013
47	Lactic acid	$C_3H_6O_3$	90.08	Root, Fruit	An et al., 2011; Liu et al., 2016
48	Tartaric acid	$C_4H_6O_6$	150.09	Root	An et al., 2011; Hou et al., 2020
49	Oxalic acid	$C_2H_2O_4$	90.03	Fruit	An et al., 2011
50	Succinic acid	$C_4H_6O_4$	118.09	Flower	An et al., 2011
51	Malic acid	$C_4H_6O_5$	134.09	Fruit	An et al., 2011; Liu et al., 2016
52	Protocatechuic acid	$C_7H_6O_4$	154.12	Fruit	Liang, 1986
53	Citric acid	$C_6H_8O_7$	192.12	Fruit	An et al., 2011; Liu et al., 2016
54	P-coumaric acid	$C_9H_80_3$	164.16	Fruit	Fu et al., 2020
55	Gallic acid	$C_7H_6O_5$	170.12	Fruit	Fu et al., 2020
56	Syringic acid	$C_9H_{10}O_5$	198.17	Fruit	Fu et al., 2020
57	p-hydroxybenzoic acid	$C_7H_6O_3$	138.12	Fruit	Fu et al., 2020
58	Caffeic acid	$C_9H_8O_4$	180.16	Fruit	Fu et al., 2020
59	Gallic acid	$C_7H_6O_5$	170.12	Fruit, Leaf	Xie et al., 2017
60	Pyrogallic acid	$C_6H_6O_3$	126.11	Fruit	Li et al., 2016a
61	Ellagic acid	$C_{14}H_6O_8$	302.19	Fruit	Hou et al., 2020; Liang et al., 2019b; Tan et al., 2019; Xie et al., 2017
62	9,12,15-octadecatrienoic acid	$C_{18}H_{30}O_2$	278.44	Fruit	Fu et al., 2020
63	9,12-octadecadienoic acid	$C_{18}H_{32}O_2$	280.45	Fruit	Fu et al., 2020
64	Chlorogenic acid	$C_{16}H_{18}O_9$	354.31	Fruit, Leaf	Xie et al., 2017
65	Ellagic acid glucuronide	$C_{21}H_{16}O_{13}$	476.35	Fruit	Hou et al., 2020

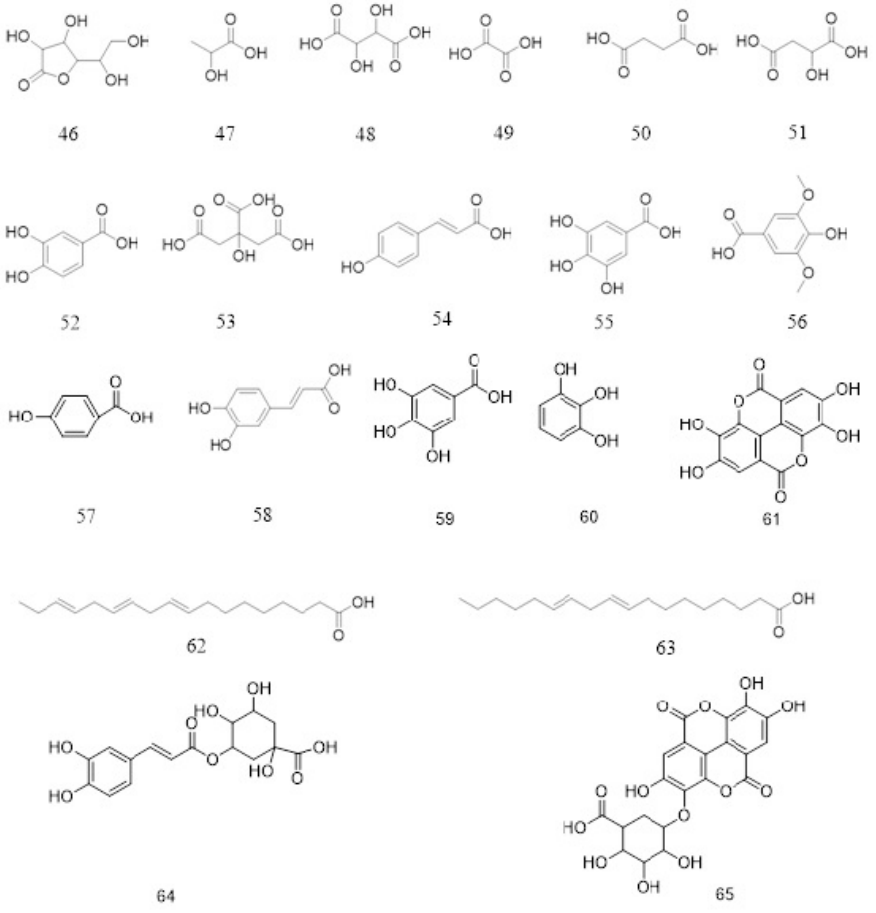


Figure 3. Chemical structures of Organic acids reported in RRT (46-65).

Table 4. Phenolic compounds isolated from Rosa roxburghii (66-78).

No.	Chemical compound	Formula	Molecular weight (g/mol)	Part of plant	Ref.
66	Procyanidin B1	$C_{30}H_{26}O_{12}$	579.14	Fruit	Fu et al., 2020
67	Procyanidin B2	$C_{30}H_{26}O_{12}$	579.14	Fruit	Fu et al., 2020
68	Procyanidin B3	$C_{30}H_{26}O_{12}$	579.14	Fruit	Fu et al., 2020
69	Fisetinidol-(4α,8)-catechin	$C_{30}H_{26}O_{11}$	561.14	Fruit	Fu et al., 2020
70	Rugosin F	$C_{82}H_{56}O_{52}$	1873.30	Fruit	Yoshida et al., 1987
71	Roxbin B	$C_{41}H_{28}O_{26}$	936.65	Fruit	Yoshida et al., 1987
72	Roxbin A	$C_{75}H_{50}O_{47}$	1703.18	Fruit	Yoshida et al., 1987
73	Pedunculagin	$C_{34}H_{24}O_{22}$	784.54	Fruit	Yoshida et al., 1987
74	Casuarictin	$C_{41}H_{28}O_{26}$	936.65	Fruit	Yoshida et al., 1987
75	Alnusiin	$C_{41}H_{26}O_{26}$	934.63	Fruit	Yoshida et al., 1987
76	Stachyurin	$C_{41}H_{28}O_{26}$	936.65	Fruit	Yoshida et al., 1987
77	Tellimagrandin II	$C_{41}H_{30}O_{26}$	938.67	Fruit	Yoshida et al., 1987
78	Strictinin isomers	$C_{26}H_{20}O_{19}$	636.43	Fruit	Ma et al., 2020

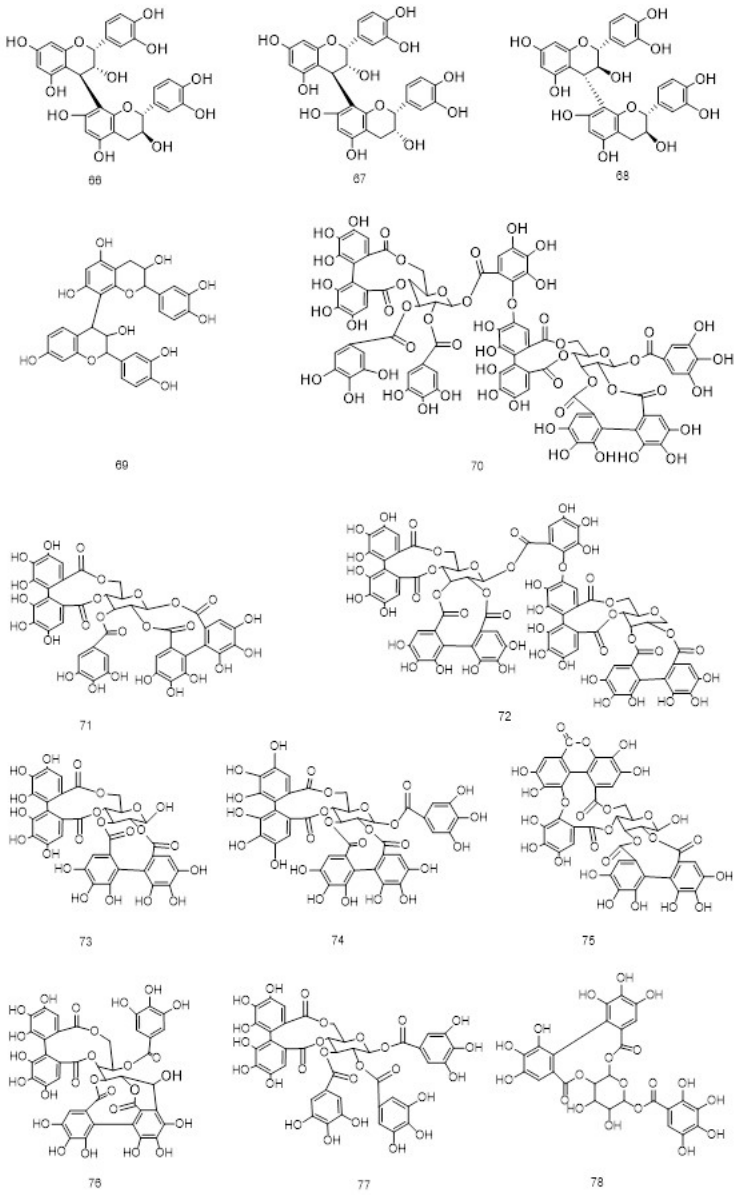


Figure 4. Chemical structures of Phenolic compounds reported in RRT (66-78).

Table 5. Polysaccharides isolated from Rosa roxburghii.

name	compose	The molar ratio (%)	molecular weight (Da)	preparation method	Source	Ref.
novel acidic polysaccharide (RTFP-3)	Carbohydrate, Protein, Galacturonic acid, Monosaccharides, Arabinose, Galactose, Glucose, Mannose, XyloseFucose	83.12:1.78:9.47:37.20:34.14:10 .02:0.15:0.17:18.30	67200	Dried powder of R. roxburghii fruits was refluxed with 95% ethanol twice at 70 °C for 3 h to remove liposoluble compounds and impurities. The separation and purification of crude RTFP was carried out using a DEAE-Sepharose fast-flow column.	Fruit	Wang et al., 2018b
RRTP-1	Rhamnose, Arabinose, Unknown sugar, Xylose, Mannose, Galactose, Glucose	1.00:16.75:13.37:5.86:11.49:2 2.73:7.80	3200	After proteins and coloring matter were removed, RRTP-1 was isolated and purified by DEAE-cellulose and Sepharose CL-6B column chromatography from crude polysaccharide and its physicochemical properties were determined by gel permeation chromatography, GC, and IR spectrum.	Fruit	Yang, 2008; Yang et al., 2005; Yang et al., 2006
RRTP-3	Rhamnose, Arabinose, Unknown sugar, Mannose, Galactose, Glucose	1.00:5.47:1.31:3.02:15.88:1.58	52000	The crude polysaccharide was obtained from the juice of Rosa roxburhhii Tratt by concentration and precipitation with ethanol. After proteins and coloring matter were removed, RRTP-3 was isolated and purified by cellulose and Sepharose CL-6B column chromatography from crude polysaccharide, and its physicochemical properties were determined by gel permeation chromatography, GC and IR spectrum	Fruit	Yang, 2008; Yang et al., 2006
Water-soluble polysaccharides (RTFP)	Arabinose, Galactose, Glucose, Mannose, Xylose, Fucose	33.8:37.3: 20.7:1.74: 3.43: 2.95	513020	Water-soluble polysaccharides (RTFP) were extracted from Rosa roxburghii Tratt fruit through the hot water method	Fruit	Wang et al., 2018c
polysaccharides from RRT fruit (RRTPs)	Mannose, Rhamnose, Glucuronic acid, Galacturonic acid, Glucose, Galactose, Arabinose, Xylose	2.64:5.13:2.71:1.20:6.69:8.01: 1.00:1.55	332563, 183963, 11929, 5953	the response surface methodology was utilized to determine optimum conditions for extract-ing the polysaccharides from Rosa roxburghii Tratt fruit (RRTPs) using ultrasonic-assisted extraction	Fruit	Chen & Kan, 2018b
RSPs-40	Arabinose, Galactose, Glucose, Fructose, Galactouronic acid	0.24:0.37:3.22:0.27:1.44	228298	Hot water extraction and fractional alcohol precipitation technology	Fruit	Chen et al., 2019a
RSPs-60	Arabinose, Galactose, Glucose, Galactouronic acid	1.58:2.06:2.37:1.69	124144	Hot water extraction and fractional alcohol precipitation technology	Fruit	Chen et al., 2019a
RRT leaves (RLP-1.2)	galacturonic acid, glucose, galactose, arabinose	1.00:18.98:4.21:1.31	40500	Response surface methodology, DEAE-52 cellulose column, and SepharoseCL-6B column chromatography were used to purify RLP, and RLP-1.2 and RLP-2.1 were obtained.	Leaves	Wu et al., 2020a

Table 5. Continued...

name	compose	The molar ratio (%)	molecular weight (Da)	preparation method	Source	Ref.
RRT) leaves (RLP-2.1)	galacturonic acid, glucose, galactose, arabinose	1.00:6.30:2.18:0.53	29400	Response surface methodology, DEAE-52 cellulose column, and SepharoseCL-6B column chromatography were used to purify RLP, and RLP-1.2 and RLP-2.1 were obtained.	Leaves	Wu et al., 2020a
PR-1	Mannose, Ribose, Rhamnose, Glucosamine Hydrochloride, Glucuronic acid, Galacturonic acid, Glucose, Galactose, Arabinose, Fucose	2.1:0.54: 2.1: 0.26:1.5: 22.7:24.0: 26.4:19.6:0.89	6200 to 7400	An extraction assay applying microwave-assisted enzymatic treatment for polysaccharides in Rosa roxburghii were developed using response surface methodology.	Fruit	Wang et al., 2018a
RRTFP-2	Rhamnose, Arabinose, Mannose, Glucose, Galactose,	1.0:6.5:1.1:1.2:16.1	74330	The crude polysaccharide of Rosa roxburghii dried fruit was purified by ion exchange and molecular gel column chromatography to obtain RRTFP-2.	Fruit	Xie et al., 2022

2022). Zhou et al. (2017) found that the total flavonoids of RRT had a strong DPPH free radical scavenging ability (Zhou et al., 2017). Li et al. (2020) optimized the extraction process of flavonoids from RRT seeds by ultrasonic-assisted extraction, and determined that flavonoids from Rosa roxburghii seeds had certain antioxidant activity (Li et al., 2020).

3.3 Anti-atherogenic properties

Lipid metabolism disorder is the pathological basis of atherosclerosis. And Hyperlipemia is a major risk element of atherosclerosis, so improving lipid metabolism disorder is deemed an important strategy to hold back cardiovascular disease (Juźwiak et al., 2005). RRT has been known as a dietary supplement for its wealthy alimentation and bioactive products, which can perfect dyslipidemia and reduce the risk of atherosclerosis (Song & Shen, 2021). Jian et al. (2015b) reported that RRT has a remarkable anti-atherosclerosis effect, which may be due to its ability to reduce blood lipid levels, LDL-C level and prevent its aggregation in cells, reduce LDL damage caused by lipid peroxide, improve SOD activity of red blood cells, prevent the damage caused by lipid peroxidation and LDL damage, and prevent foam cells from aggregation, thus inhibiting the occurrence of atherosclerosis (Jian et al., 2015b). Zhang et al. (2001) researched the outcomes of RRT juice on in vitro oxidative revision of LDL and on LDL-induced macrophage growth and cellular cholesteryl ester CE amassing (Zhang et al., 2001). Research results manifested that RRT juice uncased its antiatherogenic effectiveness largely because of its competence to restrain the oxidative modification of LDL and to control the constitution of foam cells. It was found that RRT juice can obviously prolong the oxidation delay time of HDL and HDL-3, significantly weaken their oxidation susceptibility and reduce their TBARS value, suggesting that RRT juice contains effective anti-HDL oxidation components (Feng et al., 2000). In addition, some studies (Jian et al., 2015a) have found that RRT juice can reduce blood lipid content, cell deposition, LPO to reduce LDL damage and effectively prevent foam cells from forming in the early stage of atherosclerosis. Wang et al. (2001) by establishing an experimental model of atherosclerosis in golden hamsters, it was found that RRT can be used as an antioxidant to improve the oxidative susceptibility of low density lipoprotein and reduce the occurrence of atherosclerosis (Wang et al., 2001).

3.4 Hypoglycemic properties

The chronic presence of hyperglycemia leads to chronic damage and dysfunction of various tissues, especially the eyes, kidneys, heart, blood vessels and nerves. Chen et al. (2019c) revealed that the RRT formula beverage efficiently modified the polydipsia and polyphagia symptoms of diabetic mice, restrained body loss, expressively improved liver glycogen content, significantly lessened FGB, GSP concentration and GHb relative content, and enhanced insulin sensitivity, reflecting that the formula beverage had an assistant hypoglycemic influence on diabetic mice (Chen et al., 2019c). An et al. through the STZ-induced type 1 diabetic rat model, the hypoglycemic effect of RRT fruit wine on diabetic rats and its possible mechanism were studied from physiological and biochemical indexes and mRNA levels. The results showed that the high, middle and low dose groups of RRT fruit wine could reduce the blood sugar level of diabetic mice to different degrees compared with the model group, especially the high and middle dose groups had significant differences from the model group. Zhang et al. (2004) found that flavonoids from RRT can effectively protect the pancreas from oxidative damage caused by alloxan and prevent diabetes

(Zhang et al., 2004). Chen et al. (2021) reported the effect of RRT, RRT total polysaccharide extract (RP), and RRT total flavonoid extract (RF) on glucose and lipid metabolism disorders in type 2 diabetic mice (T2DM). RRT, RP, and RF can all build up the turmoil of glucose and lipid metabolism of T2DM mice. The effect of RP and RF is meaningfully better than that of RRT ($P < 0.05$), and the impact of RF is expressively better than that of RP and positive (Chen et al., 2021). In addition, T2DM is an acute chronic metabolic disorder characterized by senior BG and lipid metabolism disorders (Cao et al., 2018). Wang et al. (2019) reported that db/db mice were selected as model mice to value the anti-hyperglycemia and anti-hyperlipidemia activities of RTFP. The results manifest that the oral administration of RTFP could markedly reduce the body weight, fat, and liver hypertrophy and the extents of fasting blood glucose, serum insulin, and serum lipids of the db/db mice. Selenium nanoparticles functionalized with a novel polysaccharide could meaningfully inhibit H_2O_2-induced INS-1 cell apoptosis by attenuating oxidative stress and down-regulation expression of UCP-2. Their findings broadly prove that RP3-SeNPs can function as a promising candidate for the treatment of ROS-mediated diabetes (Wang et al., 2019). These findings suggest that RTFP can be used as a promising functional supplement to prevent and treat type 2 diabetes (Wang et al., 2020).

3.5 Immunoregulatory properties

For the non-specific immune function of animals, RRT can have a significant impact on it, for example, it can enhance the phagocytosis of macrophages, promote the level of serum lysozyme, increase the number of B lymphocytes, promote the body's ability to secrete antibodies, and enhance the peripheral blood T lymphocytes of mice (Wang, 2019). Zhang et al. (1998) fed the mice with RRT juice (0. 5 mL/d/mouse) for 5 days, the NK activity and the levels of IL-2, TNF-β and IFN-γ in the spleen cells of mice were significantly enhanced, indicating that the cellular immune function of mice was improved (Zhang et al.,1998). Li et al. (2019) by injecting 0.6 mL RRT extract into the stomach of mice, the spleen index and thymus index were significantly increased, and the immune function was improved (Li et al., 2019). According to a report, total triterpenes from RRT can improve the immune function inhibition induced by CTX, enhance the body's antioxidant capacity, proliferate macrophages of RAW264.7, inhibit the secretion of NO by macrophages induced by LPS, and have potential anti-inflammatory and immune activity (Tian et al., 2022). It has been reported RRT polysaccharides can significantly improve the ability of mice to resist fatigue, hypoxia, high temperature and low temperature, and improve the immunity of mice (Lu & Bao, 2002). Dietary antioxidants, especially polyphenols, have been proved to increase the expression of HO-1 in different in vitro systems. The potential use of these natural substances in regulating immune response should be carefully studied (Brambilla et al., 2008). Furthermore, Urine arsenic level in patients with arsenism caused by coal burning is closely related to the suppression of immune function. RRT preparation can efficiently build up the immune function of patients with arsenism (Li et al., 2013).

3.6 Radioprotection properties

Xu et al. (2014) by detecting the cell survival rate, the radiation protection of flavonoids from RRT was studied, the 30-day survival rate of mice and the number of colony forming units in spleen (CFU-S) after Co_{60} irradiation. Pretreatment with FRT before irradiation resulted in a significant increase in the cell survival rate at 24 h after 5 Gy irradiation, the 30-day survival rate of mice exposed to 8 Gy potentially lethal dose, and the CFU-sulfur content of mice exposed to 6 Gy dose. All these results indicate that FRT is an effective radio protective agent (Xu et al., 2014). Xu et al. (2016) investigate the radiation protective effect of RRT flavonoids and to explore the role of the Bcl- 2(Ca^{2+})/Caspase-3/PARP-1 pathway in radiation-induced apoptosis (Xu et al., 2016). And Flavonoids from RRT reduced radiation damage through PARP-1 in vivo and in vitro (Xu et al., 2020). Xu et al. (2017) conclude that FRT enhanced radioprotection at least partially by regulating PARP-1/AIF to reduce apoptosis (Xu et al., 2017). Other research suggested that FRT reinforced radioprotection at the lowest half by adjusting caspase 3/8-10, AIF, and PARP-1 to reduce apoptosis and by regulating ICAM-1, IL-1α/IL-6, TNF-α/NF-κB to weaken inflammation (Xu et al., 2018). Besides, using ultraviolet radiation to damage the cell model of skin inflammation caused by releasing self RNA from epidermal cells, it was found that the 50% aqueous extract of RRT inhibited interleukin-8 mRNA expression in normal human epidermal keratinocytes stimulated with polyinosinic: polycytidylic acid, a ligand of toll-like receptor-3 (Takayama et al., 2021). Hao et al. (2016) investigated the effect of prickly pear flavonoids on the cell cycle of radiation-injured bone marrow. The results showed that prickly pear flavonoid could reduce the G2 phase of bone marrow cells after the radiation phase and increase the proportion of cells in G1 and S phases after radiation, and had a protective effect on γ-radiation-induced bone marrow cell damage. Radiation-induced bone marrow cell injury, and showed a protective effect to a certain extent, and the protective effect was concentration-dependent within a certain concentration range (Hao et al., 2016). RRT extract has an anti-Violet radiation effect. It is hypothesized that RRT extract could be used as a novel anti-inflammatory anti-inflammatory agent for the prevention of inflammation and anti-photoaging.

3.7 Regulate the digestive system

Dyspepsia is a systemic disease of the gastrointestinal tract caused by a decrease of digestive efficiency and internal flocculation. With the improvement of people's quality of life and the change in lifestyle, its incidence is also increasing. Tu et al. (2020) made animal experiments on 15th day mice and 28th day rats, and measured indexes to evaluate the efficacy of promoting digestion. Research proves that RRT juice has the function of promoting digestion, such as RRT juice developed into food with digestive effects, which will greatly promote the development of new products in the field of food therapy (Tu et al., 2020). RTFP-3 could significantly increase the yield of total short-chain fatty acids from 23.49 to 44.29 mM, and 60.28% of total carbohydrate was consumed after 48 hours of fermentation. In addition, RTFP-3 could significantly regulate the microbial structure, reducing the ratio of scleroderma to bacteroides from

14.89 to 4.68 mM after 48 h of fermentation, and increasing the relative abundance of some beneficial intestinal microflora. RTFP treatment reversed gut symbiosis by lowering the Firmicutes-to-Bacteroidetes ratio and enhancing the relative abundances of beneficial bacteria including Bacteroidaceae, Bacteroidaceae S24-7 group, and Lactobacillaceae (Wang et al., 2020). Tu et al. (2021) study the effect of RRT on gastrointestinal motility in mice with dyspepsia, some studies have shown that RRT oral liquid has a good effect on promoting digestion and effectively promoting gastrointestinal motility (Tu et al., 2021). RRT juice has a definite therapeutic effect on acetic acid-induced gastric ulcer model rats. Zheng et al. (2017) shows that RRT juice can increase the acidity of gastric juice in rats, reduce the activity of pepsin and the number of gastric ulcer, increase the activity of SOD in gastric tissue, and at the same time reduce the content of MDA and increase the content of PGE2 in serum. The mechanism of action may be related to the fact that RRT juice promotes the increase of TFF-2, EGF and NO content, thus improving the protection and repair of gastric mucosa (Zheng et al., 2017).

3.8 Other functions

In addition to the above pharmacological activities, RRT and its extracts also have anti-stress (van der Westhuizen et al., 2008), organ protection (liver, kidney and heart) and tyrosinase inhibition activities. The research shows that RRT lyophilized powder can effectively prevent renal fibrosis and injury in rats, which is related to inhibiting oxidative stress and TGF-β1/Smads signal transduction (Zhan et al., 2019). And a study found that RRT is rich in phenolic acid in hyperlipidemic rats have a hypolipidemic effect (Wu et al., 2020b). Furthermore, it has been shown that RRT has an ameliorative effect on ether-induced psychomotor alterations (Peña et al., 2014). One finding indicates that the protective effects of a polysaccharide from RRT can be used as a natural anti-inflammatory agent to reduce chronic obesity induced colitis (Wang et al., 2022). Moreover, the compound of RRT extract can alleviate liver injury caused by alcohol, liver lipopolysaccharide signal and intestinal barrier dysfunction (Li et al., 2015). Side effects of RRT have not been reported.

4 Conclusion

In recent years, RRT has received increasing attention in China and extensive research has been conducted on its chemical composition and its pharmacological activity. At least 78 small molecular compounds including flavonoids, organic acids, tannins and 11 polysaccharide components have been isolated from RRT, and it has been found that RRT has various effects such as antioxidant, antitumor, hypoglycemic, immune modulation and anti-radiation. This will also provide more ideas for the development of functional foods for this ancient fruit.

Conflict of interest

All authors have no conflicts of interest to declare.

Funding

This work was supported by the Department of Science and Technology of Guizhou Province (Nos. QKHZC [2021] normal 476, QKHPTRC [2019]5657, QKHZC [2019]2953, QKHZC [2020]4Y072, QKHPTRC [2018]5772-001), Department of Education of Guizhou Province (QJHKY[2021]049) and Guizhou Engineering Research Center of Industrial Key-technology for Dendrobium Nobile (QJJ[2022]048 and QJJ[2022]006), Chongqing Science and Health Joint Chinese Medicine Research Project (2019ZY023205), Chongqing Key Specialties in Clinical Pharmacy Construction Project (No. YWBF[2020]68).

References

An, H. M., Liu, M., Yang, M., & Fan, W. G. (2011). Analysis of main organic acid compositions in Rosa roxburghii Tratt. *Zhongguo Nong Ye Ke Xue*, 44(10), 2094-2100.

Brambilla, D., Mancuso, C., Scuderi, M. R., Bosco, P., Cantarella, G., Lempereur, L., Benedetto, G., Pezzino, S., & Bernardini, R. (2008). The role of antioxidant supplement in immune system, neoplastic, and neurodegenerative disorders: a point of view for an assessment of the risk/benefit profile. *Nutrition Journal*, 7(1), 29. http://dx.doi.org/10.1186/1475-2891-7-29. PMid:18826565.

Cao, Y., Chen, X., Sun, Y., Shi, J., Xu, X., & Shi, Y. C. (2018). Hypoglycemic effects of pyrodextrins with different molecular weights and digestibilities in mice with diet-induced obesity. *Journal of Agricultural and Food Chemistry*, 66(11), 2988-2995. http://dx.doi.org/10.1021/acs.jafc.8b00404. PMid:29446938.

Chen, C., Tan, S. M., Wang, H., Yang, S., & Dai, X. T. (2021). Effects of Rosa roxburghii Tratt and its active ingredients on glucose and lipid metabolism in type 2 diabetic mice. *Food Science*, 2021, 1-14.

Chen, G., & Kan, J. (2018a). Characterization of a novel polysaccharide isolated from Rosa roxburghii Tratt fruit and assessment of its antioxidant in vitro and in vivo. *International Journal of Biological Macromolecules*, 107(Pt A), 166-174. http://dx.doi.org/10.1016/j.ijbiomac.2017.08.160. PMid:28866014.

Chen, G., & Kan, J. (2018b). Ultrasound-assisted extraction, characterization, and antioxidant activity in vitro and in vivo of polysaccharides from chestnut rose (Rosa roxburghii tratt) fruit. *Journal of Food Science and Technology*, 55(3), 1083-1092. http://dx.doi.org/10.1007/s13197-017-3023-8. PMid:29487451.

Chen, Q., Li, C., Huang, T., Fu, X., & Jia, Q. (2019a). Physicochemical characterization, in vitro antioxidant and α-glucosidase inhibitory activity of polysaccharides from Rosa sterilis fruit. *Modern Food Science and Technology*, 35(11), 114-119.

Chen, X. M., Tan, S. M., Huang, Y., Chen, P., & Song, C. J. (2019b). Hypoglycemic effect of Rosa roxburghii juice on type I diabetic mice. *Xiandai Shipin Keji*, 35(8), 13-20.

Chen, X. M., Tan, S. M., Huang, Y., Chen, P., & Song, C. J. (2019c). Hypoglycemic effect of Rosa roxburghii, morus alba and momordica charantia beverage on diabetic mice. *China Brewing*, 38(6), 123-127.

Chen, Y., Liu, Z. J., Liu, J., Liu, L. K., Zhang, E. S., & Li, W. L. (2015). Inhibition of metastasis and invasion of ovarian cancer cells by crude polysaccharides from rosa roxburghii tratt in vitro. *Asian Pacific Journal of Cancer Prevention*, 15(23), 10351-10354. http://dx.doi.org/10.7314/APJCP.2014.15.23.10351. PMid:25556474.

Coronado-Reyes, J. A., Cortés-Penagos, C. J., & González-Hernández, J. C. (2022). Chemical composition and great applications to the fruit of the pomegranate (Punica granatum): a review. *Food Science and Technology*, 42, e29420. http://dx.doi.org/10.1590/fst.29420.

Dai, T. T., Li, Q. J., Chen, X. Y., Wu, N. Y. Y., & Yang, X. S. (2018). Extraction and determination of total triterpenoids of Rosa roxburghii Tratt. *Journal of Guizhou Normal University*, 36(3), 36-39.

Dai, T. T., Li, Q. J., Nan, Y., & Yang, X. S. (2015). Chemical components of antioxidant activity parts of Rosa roxburghii fruit. *Zhongguo Shiyan Fangjixue Zazhi*, 21(21), 62-65.

Dai, Z. K., Yu, L. M., Yang, X. S., Shi, J. S., & Wen, G. R. (2005). Inhibitive effect of CL an extract of Rosa roxburgbii Tratt on growth of gastric carcinoma cell lines in vitro. *Guizhou Medical Journal*, 29(9), 20-23.

Ding, Y.-T., Zheng, Z.-H., Zhao, R.-Y., Zhang, N., Sun, Y.-J., Li, J.-H., Wang, J.-H., Luo, J., Jia, S.-S., & Sun, Y.-K. (2020). Rapid identification of chemical constituents in psoralea coryifolia by UPLC-Q-TOF-MSE combined with unifi informatics platform. *Journal of Chinese Mass Spectrometry Society*, 41(1), 76-86.

Feng, L. L., Zhang, C. N., & Zhuang, Y. Y. (2000). Inhibitory effect of Rosa roxburghii juice on oxidative modification of human high density lipoprotein and its subcomponents. *Journal of Clinical Laboratory Science*, 18(1), 34-35.

Fu, Y. Y., Liu, J. M., Lu, X. L., Peng, Q. R., Xie, Y. C., & Yang, M. (2020). Research progress on main active components and pharmacological effects of Rosa roxburghii Tratt. *Science and Technology of Food Industry*, 41(13), 328-335.

Hao, M. H., Xu, P., Li, Y. N., & Wang, L. J. (2016). Effect of flavonoids of rosaroxburghii tratt on the cell cycle of bone marrow cells damaged by radiation. *Xinxiang Yixueyuan Xuebao*, 33(12), 1044-1046.

Hao, M. H., Zhang, F., Liu, X. X., Zhang, F., Wang, L. J., Xu, S. J., Zhang, J. H., Ji, H. L., & Xu, P. (2018). Qualitative and quantitative analysis of catechin and quercetin in flavonoids extracted from Rosa roxburghii Tratt. *Tropical Journal of Pharmaceutical Research*, 17(1), 71-76. http://dx.doi.org/10.4314/tjpr.v17i1.11. PMid:30853875.

Hou, Z., Yang, H., Zhao, Y., Xu, L., Zhao, L., Wang, Y., & Liao, X. (2020). Chemical characterization and comparison of two chestnut rose cultivars from different regions. *Food Chemistry*, 323, 126806. http://dx.doi.org/10.1016/j.foodchem.2020.126806. PMid:32330647.

Huang, D., Li, C., Chen, Q., Xie, X., Fu, X., Chen, C., Huang, Q., Huang, Z., & Dong, H. (2022). Identification of polyphenols from Rosa roxburghii Tratt pomace and evaluation of in vitro and in vivo antioxidant activity. *Food Chemistry*, 377, 131922. http://dx.doi.org/10.1016/j.foodchem.2021.131922. PMid:34979396.

Huang, J. E., Jiang, J. Y., Luo, Y., & Dai, Z. K. (2013). Effect of Rosa roxburghii Tratt triterpene on proliferation of human hepatoma SMMC-7721 cells. *Shipin Kexue*, 34(13), 275-279.

Jian, C. D., Li, X. W., Huang, J. M., Meng, L. Q., & Yuan, S. S. (2015a). Study on the relationship between the anti-atherosclerotic effect of CL juice and superoxide dismutase. *Inner Mongolia Chinese Medicine*, 34(6), 108.

Jian, C. D., Lu, W. X., Tang, X. L., Huang, X. H., & Chen, H. Y. (2015b). Study on the anti-atherosclerotic effect of Rosa roxburghii Tratt. *Asia-Pacific Traditional Medicine*, 11(8), 10-11.

Juźwiak, S., Wójcicki, J., Mokrzycki, K., Marchlewicz, M., Białecka, M., Wenda-Rózewicka, L., Gawrońska-Szklarz, B., & Droździk, M. (2005). Effect of quercetin on experimental hyperlipidemia and atherosclerosis in rabbits. *Pharmacological Reports*, 57(5), 604-609. PMid:16227643.

Köten, M., & Ünsal, A. S. (2022). Nutritional, chemical and cooking properties of noodles enriched with terebinth (Pistacia Terebinthus) fruits roasted at different temperatures. *Food Science and Technology*, 42, e47120. http://dx.doi.org/10.1590/fst.47120.

Kuhn, S. O., Meissner, K., Mayes, L. M., & Bartels, K. (2018). Vitamin C in sepsis. *Current Opinion in Anaesthesiology*, 31(1), 55-60. http://dx.doi.org/10.1097/ACO.0000000000000549. PMid:29176375.

Li, H., Qiu, P., Wang, J., Niu, C., & Pan, S. (2015). Effects of compound Ginkgo biloba on intestinal permeability in rats with alcohol-induced liver injury. *Food & Function*, 6(2), 470-478. http://dx.doi.org/10.1039/C4FO00739E. PMid:25473797.

Li, J., Zhang, A. H., Ren, Y. J., Liu, Z. Y., Huang, X. X., & Yang, D. P. (2013). Regulating effects of Rosa roxburghii tratt preparation on immune function in arseniasis patients caused by coal burning. *Chinese Journal of Preventive Medicine*, 47(9), 783-787. PMid:24351556.

Li, M. D., Luo, K., & Huang, X. F. (2020). Ultrasonic-assisted extraction of flavone from Rosa roxburghii seeds and its antioxidant activity in vitro. *Journal of Hubei Minzu University*, 38(1), 7-12.

Li, M.-Y., Qiu, R.-C., Yang, J.-P., Yao, G.-J., Wang, C.-L., Cheng, W., & Li, W.-T. (2019). Effects of Rosa roxburghii tratt extracts on immune organindex, blood parameters and antioxidant function in mice. *Chinese Journal of Veterinary Medicine*, 55(9), 51-54.

Li, Q. J., Nan, Y., Qin, J. J., Yang, Y., Hao, X. J., & Yang, X. S. (2016a). Chemical constituents from medical and edible plants of Rosa roxburghii. *Zhongguo Zhongyao Zazhi*, 41(3), 451-455. PMid:28868863.

Li, Q. J., Nan, Y., Yang, Y., Wang, D. P., & Yang, X. S. (2016b). Determination of kaiiichigeside F1 from the medical and edible plants of Rose roxburghii by HPLC. *Chinese Journal of Ethnomedicine and Ethnopharmacy*, 25(9), 22-23.

Li, Q. J., Nan, Y., Yang, Y., Wang, D. P., & Yang, X. S. (2016c). Simultaneous determination of two triterpenoids components from Rose roxburghii by HPLC. *Guizhou Agricultural Sciences*, 44(9), 125-128.

Liang, G. Y. (1986). Research on the chemical composition of Rosa roxburghii Tratt. *Chinese Herbal Medicines*, 17(11), 4-6.

Liang, G. Y. (1987). The isolation and structure of roxburic acid. *Yao Xue Xue Bao*, 22(2), 121-125. PMid:3618237.

Liang, G. Y., Zheng, Y. Y., He, Z. Y., Zhang, J. X., & Yang, J. G. (2001). Studies on the compound of fruit juice of Rosa roxburghii Tratt. *Guizhou Science*, 3, 5-7.

Liang, M. L., Li, Q., Long, Y. B., Li, Y., Li, P., & Yuan, X. H. (2019a). Identification of chemical constituents of Rosa roxbunghii and their antibacterial activities. *Guizhou Agricultural Sciences*, 47(5), 10-13.

Liang, Q., Wu, Q., Wu, J. F., Li, L. L., Chen, W. S., & Jiang, F. (2019b). Investigation of extraction process and establishment of content determination method for Rosa roxburghii root polyphenols. *Lishizhen Medicine and Materia Medica Research*, 30(2), 319-322.

Liu, H.-L., Chen, D.-X., Fang, N., Yu, L.-M., Liu, J.-W., Liu, Z.-L., Wen, G.-R., Yang, X.-S., Xiao, Y., Qi, Y., Xiao, J.-H., Wan, W.-H., & Hu, X.-J. (2006). Effects of Rosa roxburghii Tratt extract-CL1 on gastric carcinoma SGC-7901 cells growth and human umbilical cord $CD34^+$ cells proliferation and differentiation. *Chinese Journal of Clinical Pharmacology and Therapeutics*, 11(7), 829-832.

Liu, M. H., Zhang, Q., Zhang, Y. H., Lu, X. Y., Fu, W. M., & He, J. Y. (2016). Chemical analysis of dietary constituents in Rosa roxburghii and Rosa sterilis fruits. *Molecules*, 21(9), 1204. http://dx.doi.org/10.3390/molecules21091204. PMid:27618004.

Liu, W., Li, S. Y., Huang, X. E., Cui, J. J., Zhao, T., & Zhang, H. (2012). Inhibition of tumor growth in vitro by a combination of extracts from Rosa roxburghii Tratt and fagopyrum cymosum. *Asian Pacific Journal of Cancer Prevention*, 13(5), 2409-2414. http://dx.doi.org/10.7314/APJCP.2012.13.5.2409. PMid:22901230.

Liu, Y. X., & Yuan, X. H. (2021). Study on technology extracting rosolic acid of Rosa roxbunghii Tratt. pomace. *Hubei Agricultural Sciences*, 60(5), 103-107.

Lu, F. T., & Bao, S. J. (2002). Effect of polysaccharides from fructus Rosa roxburghii on stress tolerance and immune function. *Journal of Guangzhou University of Traditional Chinese Medicine*, 19(2), 141-142.

Luo, S. Y., Tan, B. B., Liao, J. W., Yang, Z. M., & Wang, Q. X. (2002). Somatological study on the protective effect of Rosa roxburghii Tratt on mitochondrial damage in aging mice kidney. *Journal of Sichuan of Traditional Medicine*, 20(1), 8-9.

Ma, Y. X., Zhu, Y., Wang, C. F., Wang, Z. S., Chen, S. Y., Shen, M. H., Gan, J. M., Zhang, J. G., Gu, Q., & He, L. (1997). The aging retarding effect of 'Long-Life CiLi'. *Mechanisms of Ageing and Development*, 96(1-3), 171-180. http://dx.doi.org/10.1016/S0047-6374(97)01890-3. PMid:9223119.

Ma, Y., Wang, Y., Zhang, H., Sun, W., Li, Z., Zhang, F., Zhang, H., Chen, F., Zhang, H., An, J., & He, C. (2020). Antimicrobial mechanism of strictinin isomers extracted from the root of Rosa roxburghii Tratt (Ci Li Gen). *Journal of Ethnopharmacology*, 250, 112498. http://dx.doi.org/10.1016/j.jep.2019.112498. PMid:31877366.

Peña, I. J. I., Yoon, S. Y., Peña, J. B., Park, S., Yoon, B., Kim, H. J., Paek, S. H., Seo, Y. K., Moon, B. S., & Cheong, J. H. (2014). The ameliorating effect of Rosa roxburghii against ethanol-induced psychomotor alterations in rats. *The American Journal of Drug and Alcohol Abuse*, 40(1), 75-81. http://dx.doi.org/10.3109/00952990.2013.846349. PMid:24266614.

Porter, E. A., van den Bos, A. A., Kite, G. C., Veitch, N. C., & Simmonds, M. S. (2012). Flavonol glycosides acylated with 3-hydroxy-3-methylglutaric acid as systematic characters in Rosa. *Phytochemistry*, 81, 90-96. http://dx.doi.org/10.1016/j.phytochem.2012.05.006. PMid:22721781.

Qiang, H. J., Zhang, C. N., Chen, G. Y., & Zhuang, Y. Y. (2000). Effects of rose roxburghii tratt juice (RRTJ) on the growth of human leukemia K562 cells. *Chinese Journal of Clinical Oncology and Rehabilitation*, 7(4), 34-36.

Ruiz-Cisneros, M. F., Ornelas-Paz, J. J., Olivas-Orozco, G. I., Acosta-Muñiz, C. H., Salas-Marina, M. Á., Molina-Corral, F. J., Berlanga-Reyes, D. I., Fernández-Pavía, S. P., Cambero-Campos, O. J., & Rios-Velasco, C. (2022). Effect of rhizosphere inoculation with Bacillus strains and phytopathogens on the contents of volatiles and human health-related compounds in tomato fruits. *Food Science and Technology*, 42, e51120. http://dx.doi.org/10.1590/fst.51120.

Singh, D. V., Gupta, M. M., Tripathi, A. K., Prajapati, V., & Kumar, S. (2004). Arjunetin from terminalia arjuna as an insect feeding-deterrent and growth inhibitor. *Phytotherapy Research*, 18(2), 131-134. http://dx.doi.org/10.1002/ptr.1383. PMid:15022165.

Song, P., & Shen, X. (2021). Proteomic analysis of liver in diet-induced hyperlipidemic mice under fructus Rosa roxburghii action. *Journal of Proteomics*, 230, 103982. http://dx.doi.org/10.1016/j.jprot.2020.103982. PMid:32927110.

Takayama, S., Kawanishi, M., Yamauchi, K., Tokumitsu, D., Kojima, H., Masutani, T., Iddamalgoda, A., Mitsunaga, T., & Tanaka, H. (2021). Ellagitannins from Rosa roxburghii suppress poly(I:C)-induced IL-8 production in human keratinocytes. *Journal of Natural Medicines*, 75(3), 623-632. http://dx.doi.org/10.1007/s11418-021-01509-x. PMid:33830449.

Tan, D. H., Wang, P. Q., Zhang, S., Zhao, M., Liu, Y., Zhang, M., & Gao, X. (2019). Study on content determination of ellagic acid in different medicinal parts of Rosa roxburghii and in vitro antioxidant activity of its ethanol extract. *China Pharmacy*, 30(9), 1236-1240.

Tian, H. Z., Zhou, Y. M., Zhao, Y. B., Zang, J., & Hu, R. (2009a). Quantitative analysis of rutin in Rosa roxburghii Tratt fruit by HPLC. *Shipin Kexue*, 30(10), 203-205.

Tian, Q., Li, L., Peng, M., Li, Y., Niu, Z., Li, Q., Wang, T., & Yang, X. (2022). Immunocompetence of total triterpenoids from Rosa roxburghii Tratt fruit. *Journal of Northwest A&F University*, 50(6), 11-19.

Tian, Y., Cao, P. X., Liang, G. Y., & Xu, B. X. (2009b). An investigation in chemical constituents of chestnut rose(Rosa roxburghii) leaves. *Journal of Mountain Agriculture and Biology*, 28(4), 366-368.

Tu, Y. L., Tan, S. M., Zhou, H. X., & Luo, J. W. (2021). Effect of Rose roxburghii Tratt oral liquid on gastrointestinal motility in dyspepsia mice. *Xiandai Shipin Keji*, 37(1), 17-23.

Tu, Y. L., Zhou, H. X., Tan, S. M., & Luo, J. W. (2020). Study on the digestive function of Rose roxburghii Tratt. *Shipin Yu Fajiao Gongye*, 46(24), 85-89.

van der Westhuizen, F. H., van Rensburg, C. S. J., Rautenbach, G. S., Marnewick, J. L., Loots, D. T., Huysamen, C., Louw, R., Pretorius, P. J., & Erasmus, E. (2008). In vitro antioxidant, antimutagenic and genoprotective activity of Rosa roxburghii fruit extract. *Phytotherapy Research*, 22(3), 376-383. http://dx.doi.org/10.1002/ptr.2330. PMid:18167049.

Wang, D. J., Lu, M., Ludlow, R. A., Zeng, J. W., Ma, W. T., & An, H. M. (2021). Comparative ultrastructure of trichomes on various organs of Rosa roxburghii. *Microscopy Research and Technique*, 84(9), 2095-2103. http://dx.doi.org/10.1002/jemt.23765. PMid:33934435.

Wang, H. Z. (2018). *Analysis of effective composition in Rosa roxburghii Tratt and its bioactivity in vitro* (Doctoral dissertation). Jilin University, Changchun.

Wang, H., Huang, C., Liu, S. Y., & Du, W. (2013). Determination of myricetin and quercetin in Rose roxburghii by HPLC. *Zhongguo Shiyan Fangjixue Zazhi*, 19(1), 109-111.

Wang, H., Li, Y., Ren, Z., Cong, Z., Chen, M., Shi, L., Han, X., & Pei, J. (2018a). Optimization of the microwave-assisted enzymatic extraction of Rosa roxburghii Tratt polysaccharides using response surface methodology and its antioxidant and α-D-glucosidase inhibitory activity. *International Journal of Biological Macromolecules*, 112, 473-482. http://dx.doi.org/10.1016/j.ijbiomac.2018.02.003. PMid:29412175.

Wang, J. J., Liu, X. C., Liu, X. L., Zhuang, Y. Y., & Li, L. Y. (2001). Effect of Rose roxburghii Tratt juice on atherosclerosis in hypercholesterolemic hamsters. *Chinese Journal of Arteriosclerosis*, 9(1), 17-20.

Wang, L. L., & An, H. M. (2013). Optimized HPLC method for analyzing Vc content in Rosa roxburghii fruits. *Xiandai Shipin Keji*, 29(2), 397-400.

Wang, L., Chen, C., Zhang, B., Huang, Q., Fu, X., & Li, C. (2018b). Structural characterization of a novel acidic polysaccharide from Rosa roxburghii Tratt fruit and its α-glucosidase inhibitory activity. *Food & Function*, 9(7), 3974-3985. http://dx.doi.org/10.1039/C8FO00561C. PMid:29974117.

Wang, L., Li, C., Huang, Q., & Fu, X. (2019). Biofunctionalization of selenium nanoparticles with a polysaccharide from Rosa roxburghii fruit and their protective effect against H_2O_2-induced apoptosis in INS-1 cells. *Food & Function*, 10(2), 539-553. http://dx.doi.org/10.1039/C8FO01958D. PMid:30662993.

Wang, L., Li, C., Huang, Q., & Fu, X. (2020). Polysaccharide from Rosa roxburghii Tratt fruit attenuates hyperglycemia and hyperlipidemia and regulates colon microbiota in diabetic db/db mice. *Journal of Agricultural and Food Chemistry*, 68(1), 147-159. http://dx.doi.org/10.1021/acs.jafc.9b06247. PMid:31826616.

Wang, L., Zhang, B., Xiao, J., Huang, Q., Li, C., & Fu, X. (2018c). Physicochemical, functional, and biological properties of water-soluble polysaccharides from Rosa roxburghii Tratt fruit. *Food Chemistry*, 249, 127-135. http://dx.doi.org/10.1016/j.foodchem.2018.01.011. PMid:29407915.

Wang, L., Zhang, P., Li, C., Xu, F., & Chen, J. (2022). A polysaccharide from Rosa roxburghii Tratt fruit attenuates high-fat diet-induced intestinal barrier dysfunction and inflammation in mice by modulating the gut microbiota. *Food & Function*, 13(2), 530-547. http://dx.doi.org/10.1039/D1FO03190B. PMid:34932054.

Wang, W. F. (2019). Interpretation of the research status and development prospect of Rosa roxburghii products. *Nong Jia Can Mou*, 5, 51.

Wang, Z. W., Shen, S., & Hu, X. B. (2014). Extracting total flavonoids from Rosa roxburghii Tratt with ultrasonic wave and determination by HPLC. *Hubei Agricultural Sciences*, 53(19), 4684-4687.

Westfall, S., & Pasinetti, G. M. (2019). The gut microbiota links dietary polyphenols with management of psychiatric mood disorders. *Frontiers in Neuroscience*, 13, 1196. http://dx.doi.org/10.3389/fnins.2019.01196. PMid:31749681.

Wu, H., Li, M., Yang, X., Wei, Q., Sun, L., Zhao, J., & Shang, H. (2020a). Extraction optimization, physicochemical properties and antioxidant and hypoglycemic activities of polysaccharides from roxburgh rose (Rosa roxburghii Tratt.) leaves. *International Journal of Biological Macromolecules*, 165(Pt A), 517-529. http://dx.doi.org/10.1016/j.ijbiomac.2020.09.198. PMid:33002536.

Wu, P. H., Han, S. C., & Wu, M. H. (2020b). Beneficial effects of hydroalcoholic extract from Rosa roxburghii Tratt fruit on hyperlipidemia in high-fat-fed rats. *Acta Cardiologica Sinica*, 36(2), 148-159. PMid:32201466.

Xie, G. F., Xu, X. Y., Wang, R., Liu, Z. G., Zhou, X. L., & Yang, H. T. (2017). Analysis of phenolic, Vc and antioxidant activity of fruits and leaves of Rosa sterilis D. Shi. *Zhiwu Kexue Xuebao*, 35(1), 122-127.

Xie, Jing, H. D., Li, Y. X., Lilang, Yu, W., Qiji, L., Zhongsheng, L., & Juan, Y. (2022). Structure analysis and NGF-Like neurotrophic activity of polysaccharides RRTFP-2 from Rosa roxburghii Tratt. *Food Science and Technology*, 47(4), 224-230.

Xu, G. P., Zhang, C. N., Wang, J. J., Zhou, Y., Liu, Q., Li, K., & Zhang, S. Q. (2006). Study on the inhibitory effect of Rosa roxburghii juice and Noni juice on human ovarian cancer cell line COC_2. *Chinese Journal of Clinical Laboratory Science*, 24(2), 137-139.

Xu, P., Cai, X., Zhang, W., Li, Y., Qiu, P., Lu, D., & He, X. (2016). Flavonoids of Rosa roxburghii Tratt exhibit radioprotection and anti-apoptosis properties via the Bcl-2(Ca^{2+})/Caspase-3/PARP-1 pathway. *Apoptosis*, 21(10), 1125-1143. http://dx.doi.org/10.1007/s10495-016-1270-1. PMid:27401922.

Xu, P., Liu, X., Xiong, X., Zhang, W., Cai, X., Qiu, P., Hao, M., Wang, L., Lu, D., Zhang, X., & Yang, W. (2017). Flavonoids of Rosa roxburghii Tratt exhibit anti-apoptosis properties by regulating PARP-1/AIF. *Journal of Cellular Biochemistry*, 118(11), 3943-3952. http://dx.doi.org/10.1002/jcb.26049. PMid:28398610.

Xu, P., Zhang, W. B., Cai, X. H., Lu, D. D., He, X. Y., Qiu, P. Y., & Wu, J. (2014). Flavonoids of Rosa roxburghii Tratt act as radioprotectors. *Asian Pacific Journal of Cancer Prevention*, 15(19), 8171-8175. http://dx.doi.org/10.7314/APJCP.2014.15.19.8171. PMid:25339001.

Xu, S. J., Wang, X., Wang, T. Y., Lin, Z. Z., Hu, Y. J., Huang, Z. L., Yang, X. J., & Xu, P. (2020). Flavonoids from Rosa roxburghii Tratt prevent reactive oxygen species-mediated DNA damage in thymus cells both combined with and without PARP-1 expression after exposure to radiation in vivo. *Aging*, 12(16), 16368-16389. http://dx.doi.org/10.18632/aging.103688. PMid:32862153.

Xu, S. J., Zhang, F., Wang, L. J., Hao, M. H., Yang, X. J., Li, N. N., Ji, H. L., & Xu, P. (2018). Flavonoids of Rosa roxburghii Tratt offers protection against radiation induced apoptosis and inflammation in mouse thymus. *Apoptosis*, 23(9-10), 470-483. http://dx.doi.org/10.1007/s10495-018-1466-7. PMid:29995207.

Yang, J. T. (2008). *Isolation and purification, physicochemical properties and biological activity of Rosa roxburghii Tratt polysaccharides* (Master's thesis). Guizhou University, Guiyang.

Yang, J., Chen, F. X., & Liang, G. Y. (2005). Studyies on physicochemical properties and anti-hypoxia activity of polysaccharide RRTP-1 from Rosa roxburghii. *Zhongguo Yao Xue Za Zhi*, 40(23), 1775-1778.

Yang, J., Yang, F. Y., & Sun, Q. Y. (2006). Study on isolation and neurotrophic activity of ploysaccharides from Rosa roxburghii. *Zhongguo Yao Xue Za Zhi*, 41(13), 980-982.

Yang, Q.-Q., Zhang, D., Farha, A. K., Yang, X., Li, H.-B., Kong, K.-W., Zhang, J.-R., Chan, C.-L., Lu, W.-Y., Corke, H., & Gan, R.-Y. (2020). Phytochemicals, essential oils, and bioactivities of an underutilized wild fruit Cili (Rosa roxburghii). *Industrial Crops and Products*, 143, 111928. http://dx.doi.org/10.1016/j.indcrop.2019.111928.

Yang, Y., Li, S. Y., & Guo, Q. (2019). Study on extraction and antibactereial effect of rutin form Rosa roxburghii. *Biological Chemical Engineering*, 5(6), 28-30.

Yin, M., Xie, J., Xie, C., Luo, M., & Yang, X. (2022). Extration, identification and stability ananlysis of anthocyanins from organic Guizhou blueberries in China. *Food Science and Technology*, 42, e33520. http://dx.doi.org/10.1590/fst.33520.

Yoshida, T., Chen, X. M., Hatano, T., Fukushima, M., & Okuda, T. (1987). Tannins and related polyphenols of rosaceous medicinal plants. IV. Roxbins A and B from Rosa roxburghii fruits. *Chemical & Pharmaceutical Bulletin*, 35(5), 1817-1822. http://dx.doi.org/10.1248/cpb.35.1817. PMid:3664796.

Yu, Y. H., Gu, W. T., Ding, Z. H., Chen, S. Q., Song, Y. T., & Wang, Y. (2020). Optimization on biotransformation of quercetin glycosides in Rosa roxburghii by β-glucosidase. *Journal of Food Science and Technology*, 38(5), 109-118.

Yuan, H., Wang, Y., Chen, H., & Cai, X. (2020). Protective effect of flavonoids from Rosa roxburghii Tratt on myocardial cells via autophagy. *3 Biotech*, 10(2), 58. http://dx.doi.org/10.1007/s13205-019-2049-1. PMid:32015954.

Zeng, F. F. (2017). *Tudies on principal phytochemical composition and biological activities of Cili fruit* (Master's thesis). Zhejiang University, Hangzhou.

Zhan, J., Liu, M., Pan, L., He, L., & Guo, Y. (2019). Oxidative stress and TGF-β1/Smads signaling are involved in Rosa roxburghii fruit extract alleviating renal fibrosis. *Evidence-Based Complementary and Alternative Medicine*, 2019, 4946580. http://dx.doi.org/10.1155/2019/4946580. PMid:31531112.

Zhang, C., Liu, X., Qiang, H., Li, K., Wang, J., Chen, D., & Zhuang, Y. (2001). Inhibitory effects of rosa roxburghii tratt juice on in vitro oxidative modification of low density lipoprotein and on the macrophage growth and cellular cholesteryl ester accumulation induced by oxidized low density lipoprotein. *Clinica Chimica Acta*, 313(1-2), 37-43. http://dx.doi.org/10.1016/S0009-8981(01)00647-7. PMid:11694237.

Zhang, H. H., Liu, L. Y., Wu, C. E., Li, T. T., Fan, G. J., & Ying, R. F. (2017). Semi-bionic extraction of flavonoids from Rosa roxburghii Tratt. *Journal of Nanjing Forestry University*, 41(6), 47-53.

Zhang, X. F., Wu, L. H., & Yao, S. Q. (1998). Effects of extract of Rosa roxburghii tratt on rat's cellular immune function. *Journal Of Xianning Medical College*, 12(3), 152-154.

Zhang, X. L. (2005). Investigation on flavonoids from Rosa roxburghii Tratt. and its biological activity (Master's thesis). East China Normal University, Shanghai.

Zhang, X. L., Qu, W. J., Sun, B., Zhang, Z. C., Niu, W., & Pan, Y. F. (2004). The preventive effect of flavoniod of Rosa roxburghii tratt on diabetic mice. *Acta Nutrimenta Sinica*, 26(6), 474-476.

Zheng, B., Qin, J. J., & Zhang, W. (2017). Effect of Cili juice on superoxide dismutase,malondialdehyde and prostaglandin E_2 of experimental gastric ulcer rats. *Zhonghua Zhongyiyao Xuekan*, 35(04), 991-993.

Zhou, Y., Guo, J. J., & Yu, J. P. (2017). Extraction process of total flavonoids from Rosa roxburghii tea and their antioxidant activity. *BioResources*, 39(02), 135-140.