红参的化学成分及药理作用研究进展

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摘　要:红参为人参常用炮制品之一,其化学成分主要有皂苷类、挥发油类、糖类、氨基酸类、微量元素等;药理作用研究发现红参主要具有增强免疫、抗肿瘤、抗氧化、抗衰老、抗疲劳、抗糖尿病、抗肝肾毒性作用等。红参在加工过程中会产生多种成分,如人参皂苷 Rg_3、人参皂苷 Rh_1、人参皂苷 Rh_2、人参炔醇、精氨酸双糖苷、麦芽酚等,这会使得红参的某些药理作用增强。本文则系统整理了 2010 ~ 2020 年红参的化学成分及药理活性的研究进展,以期为红参的质量控制、临床应用提供理论依据。

关键词:红参;化学成分;药理作用;研究进展

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Research progress on chemical constituents and pharmacological activities of Ginseng Radix et Rhizoma Rubra

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Abstract:Ginseng Radix et Rhizoma Rubra (GRRR) is one of the well-known medical materials which are made from ginseng through the Chinese traditional Medicine processing methods. Its chemical components mainly include saponins,volatile oils,sugars,amino acids,trace elements and so on. Pharmacological research activities have showed that GRRR has positive effects in enhancing immune system,anti-tumor,anti-oxidation,anti-aging,anti-fatigue,anti-diabetes,anti-hepatorenal toxicity,etc. Many components can be produced during processing,for example,ginsenosides Rg_3,Rh_1,Rh_2,panaxynol,arginyl-fructosyl-glucose,maltol,which could help strengthen the pharmacological activities of GRRR. This article,while systematizing the research progress of the chemical composition and pharmacological researches on GRRR during 2010 and 2020,is aimed to provide a theoretical basis for quality control and clinical application of GRRR.

Key words:Ginseng Radix et Rhizoma Rubra;chemical compositions;pharmacological activities;research progress

《中国药典》(2020 年版)[1]记载红参(Ginseng Radix et Rhizoma Rubra,GRRR)为五加科植物人参 *Panax ginseng* C. A. Mey. 的栽培品经蒸制后的干燥根和根茎。本品性温,味甘、微苦,具有大补元气,复脉固脱,益气摄血的功效,用于体虚欲脱,肢冷脉微,气不摄血,崩漏下血等症。现代研究发现,人参作为名贵中药材之一,本身富含有多种成分,经蒸制后发生了一系列的变化,使红参中所含成分呈现多样性[2],文献报道红参的化学成分主要为皂苷类、挥发油类、糖类、氨基酸类、微量元素等,药理作用主要

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有增强免疫、抗肿瘤、抗氧化、抗衰老、抗疲劳、抗糖尿病、抗肝肾毒性等。

红参作为人参重要的炮制品之一，在国内外临床应用广泛。查阅 2010 – 2020 年文献发现，红参在人参的综述文章仅有部分介绍[3-5]，且有关红参化学成分的研究也多关注皂苷的类型，对红参中的其他成分如挥发油类、糖类描述较少[6]，缺少对红参的化学成分及药理作用整体进行全面归纳总结的文章，故本文综合整理了近十年内红参化学成分及药理作用的研究进展，以求为临床合理利用红参的提供更为完善的科学资料。

1 红参的化学成分

1.1 皂苷类

人参皂苷在人参、红参中的含量较高，为主要的生物活性物质。其在蒸制过程会因水解反应发生不同皂苷类型间转化的现象[7]，表现为糖苷键或酯键的断裂。根据苷元部分结构类型的不同，人参皂苷分为达玛烷型四环三萜和齐墩果酸型（oleanolicacid，OLE）五环三萜，达玛烷型四环三萜又可细分为原人参二醇型（protopanaxadiol，PPD）和原人参三醇型（protopanaxatriol，PPT）。Yang[8]介绍人参中还有少量的达玛烷型的衍生物—奥克梯隆型皂苷。本文结合文献整理红参中所含人参皂苷共 62 个，其中原人参二醇型皂苷 19 个、原人参三醇型皂苷 15 个、原人参二醇型皂苷及人参三醇型皂苷的衍生物 20 个、齐墩果酸型皂苷 8 个。

1.1.1 达玛烷型四环三萜类

1.1.1.1 原人参二醇型皂苷和原人参三醇型皂苷

红参中原人参二醇型皂苷、原人参三醇型皂苷如图 1、表 1、图 2、表 2 所示。2020 年版《中国药典》以人参皂苷 Rg_1、人参皂苷 Re、人参皂苷 Rb_1 为指标，辨别红参质量的优劣。Yang 等[13]通过整理对比水参、生晒参和红参的人参皂苷的类型及结构，总结了原人参二醇型皂苷（**2** ~ **8**）、原人参三醇型皂苷（**20**、**25**、**30**、**33**）的 C-20 位取代基均为 *S* 构型。其它相关文献未载明其构型。Shi 等[14]采用超快速液相色谱 – 三重四级杆/线性离子阱质谱（UFLC-QTRAP-MS/MS）法测得不同贮藏条件下红参中原人参二醇型人参皂苷 CK（**18**）、人参皂苷 F_2（**19**）以及人参三醇型人参皂苷 F_1（**34**）的含量。亦有研究总结 **9**、**10** ~ **13**、**27**、**29** 为红参相较于人参的特有成分之一[15]。

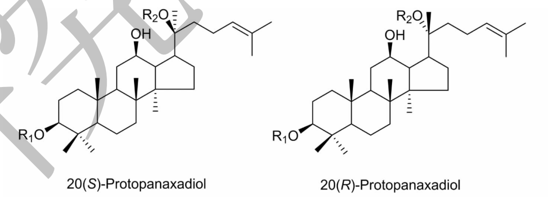

图 1 原人参二醇型皂苷结构图

Fig. 1 The structures of protopanaxadiol saponins

表 1 原人参二醇型皂苷名称表

Table 1 Name of protopanaxadiol saponins

序号 No.	化合物名称 Compound name	取代基 Substituent R_1	取代基 Substituent R_2	参考文献 Ref.
1	20(*S*)-Ginsenoside Ra_1	-glc (2-1) glc	-glc (6-1) ara(p) (4-1) xyl	13
2	Ginsenoside Ra_2	-glc (2-1) glc	-glc (6-1) ara(f) (2-1) xyl	12,13
3	Ginsenoside Ra_3	-glc (2-1) glc	-glc (6-1) glc (3-1) xyl	12,13
4	Ginsenoside Rb_1	-glc (2-1) glc	-glc (6-1) glc	9,12-14,18
5	Ginsenoside Rb_2	-glc (2-1) glc	-glc (6-1) ara(p)	12-14,18
6	Ginsenoside Rb_3	-glc (2-1) glc	-glc (6-1) xyl	12,13
7	Ginsenoside Rc	-glc (2-1) glc	-glc (6-1) ara(f)	12-14,18
8	Ginsenoside Rd	-glc (2-1) glc	-glc	12-14,18
9	20(*S*)-Ginsenoside Rg_3	-glc (2-1) glc	-H	9,12,14,19,20
10	20(*R*)-Ginsenoside Rg_3	-glc (2-1) glc	-H	9,12,14,19,20
11	20(*S*)-Ginsenoside Rh_2	-glc	-H	13
12	Ginsenoside Rs_1	-glc (2-1) glc (6) Ac	-glc (6-1) ara(p)	12,13
13	Ginsenoside Rs_2	-glc (2-1) glc (6) Ac	-glc (6-1) ara(f)	12,13

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续表 1(Continued Tab. 1)

序号 No.	化合物名称 Compound name	取代基 Substituent		参考文献 Ref.
		R_1	R_2	
14	20(*S*)-Ginsenoside Rs_3	-glc (2-1) glc (6) Ac	-glc (6-1) ara(f)	12,13
15	20(*R*)-Ginsenoside Rs_3	-glc (2-1) glc (6) Ac	-glc (6-1) ara(f)	12
16	20(*S*)-Notoginsenoside R_4	-glc (2-1) glc	-glc (6-1) glc (6-1) xyl	13
17	Quinquenoside R_1	-glc (2-1) glc (6) Ac	-glc (6-1) glc	12,13
18	20(*S*)-Ginsenoside CK	-H	-glc	14,18
19	Ginsenoside F_2	-glc	-glc	14

注:ara(f):*α-L*-arabinofuranosyl;ara(p):*α-L*-arabinopyranosyl;glc:*β-D*-glucopyranosyl;xyl:*β-D*-xylopyranosyl;Ac:acetyl。

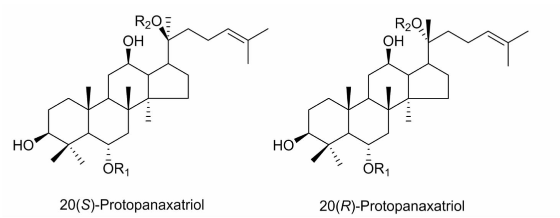

图 2 原人参三醇型皂苷结构图

Fig. 2 The structures of protopanaxatriol saponins

1.1.1.2 原人参二醇型皂苷和人参三醇型皂苷的衍生物

人参蒸制过程使原人参二醇型皂苷、原人参三醇型皂苷生成相应的衍生物,如图 3、表 3 所示。其属于红参的特有成分,如周琪乐等在系统研究中国红参中存在独特变化的 C-17 侧链的人参皂苷(**35**、**36**、**38 ~ 43**、**45**、**46 ~ 48**、**51 ~ 54**)16 个。Zhang 等[16]所总结红参特有人参皂苷(**35 ~ 39**、**43 ~ 50**)有 13 个。

表 2 原人参三醇型皂苷名称表

Table 2 Name of protopanaxatriol saponins

序号 No.	化合物名称 Compound name	取代基 Substituent		参考文献 Ref.
		R_1	R_2	
20	Ginsenoside Re	-glc (2-1) rha	-glc	9,12-14,18
21	Ginsenoside Re_2	-glc (3-1) glc	-glc	12
22	20(*S*)-Ginsenoside Rf	-glc (2-1) glc	-H	9,12-14,18
23	20(*R*)-Ginsenoside Rf	-glc (2-1) glc	-H	9,12,18
24	20(*S*)-Ginsenoside Rf-1a	-glc (4-1)-*α-D*-glc	-H	12,17,18
25	Ginsenoside Rg_1	-glc	-glc	9,12-14
26	20(*S*)-Ginsenoside Rg_2	-glc (2-1) rha	-H	9,12-14,19
27	20(*R*)-Ginsenoside Rg_2	-glc (2-1) rha	-H	9,12-14
28	20(*S*)-Ginsenoside Rh_1	-glc	-H	9,12-14,19
29	20(*R*)-Ginsenoside Rh_1	-glc	-H	9,12-14,19
30	Notoginsenoside R_1	-glc (2-1) xyl	-glc	12,13
31	20(*S*)-Notoginsenoside R_2	-glc (2-1) xyl	-H	9,12
32	20(*R*)-Notoginsenoside R_2	-glc (2-1) xyl	-H	9,12
33	20-Gluco-ginsenoside Rf	-glc (2-1) glc	-glc	12,13
34	Ginsenoside F_1	-H	-glc	14

注:glc:*β-D*-glucopyranosyl;rha:*α-L*-rhamnopyranosyl;xyl:*β-D*-xylopyranosyl。

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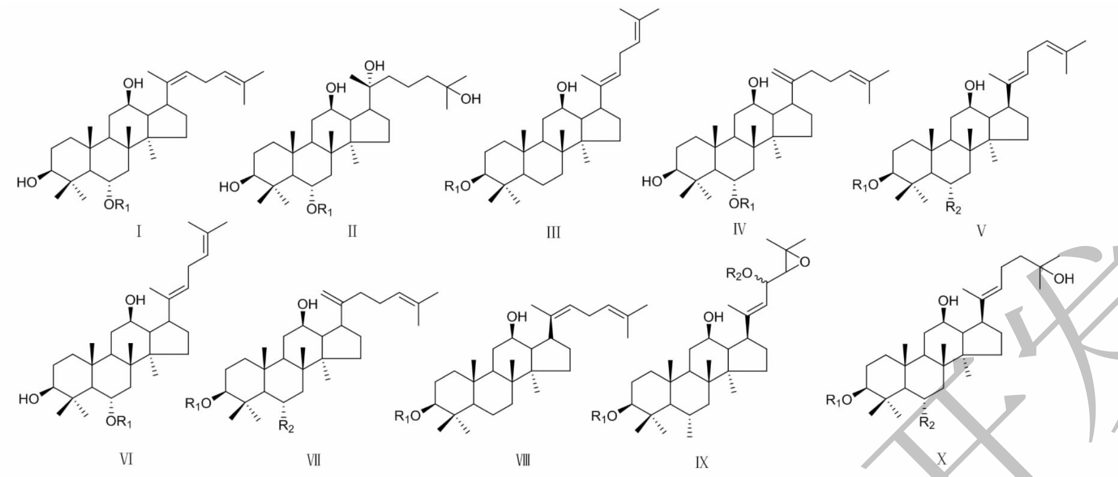

图 3 原人参二醇型皂苷和原人参三醇型皂苷的衍生物结构图

Fig. 3 The derivative structures of protopanaxadiol saponins and protopanaxatriol saponins

表 3 原人参二醇型皂苷和原人参三醇型皂苷的衍生物名称表

Table 3 Derivative name of protopanaxadiol saponins and protopanaxatriol saponins

序号 No.	化合物名称 Compound name	结构 Structure	取代基 Substituent R₁	取代基 Substituent R₂	参考文献 Ref.
35	20(22)*E*-Ginsenoside F_4	Ⅰ	-glc (2-1) rha	–	10,12,13,16
36	20(22)*Z*-Ginsenoside F_4	Ⅰ	-glc (2-1) rha	–	10,12,13,16
37	20(*R*)-Ginsenoside Rf_2	Ⅱ	-glc (2-1) rha	–	11,13,16
38	Ginsenoside Rg_5	Ⅲ	-glc (2-1) glc	–	12,13,16,20
39	Ginsenoside Rg_6	Ⅳ	-glc (2-1) rha	–	12,13,16
40	20(22)*E*-Ginsenoside Rg_9	Ⅴ	-H	-*O*-glc (2-1) glc	12
41	20(22)*E*-Ginsenoside Rh_4	Ⅵ	-glc	–	9,12,13
42	20(22)*Z*-Ginsenoside Rh_4	Ⅵ	-glc	–	9,12,13
43	Ginsenoside Rk_1	Ⅶ	-glc (2-1) glc	-H	12,13,16,20
44	Ginsenoside Rk_2	Ⅶ	-glc	-H	13,16
45	Ginsenoside Rk_3	Ⅶ	-H	-*O*-glc	12,13,16
46	20(22)*Z*-Ginsenoside Rs_4	Ⅲ	-glc (2-1) glc (6) Ac	–	12,13,16,17
47	20(22)*E*-Ginsenoside Rs_4	Ⅲ	-glc (2-1) glc (6) Ac	–	12,13,16
48	Ginsenoside Rs_5	Ⅶ	-glc (2-1) glc (6) Ac	-H	12,13,16
49	Ginsenoside Rs_6	Ⅵ	-glc (6) Ac	–	13,16
50	Ginsenoside Rs_7	Ⅶ	-H	-glc (6) Ac	13,16
51	Ginsenoside Rz_1	Ⅷ	-glc (2-1) glc	–	12
52	23-*O*-Methylginsenoside-Rg_{11}	Ⅸ	-glc (2-1) glc	-Me	12,17
53	12*β*,25-Dihydroxy-dammar-20(22)*E*-ene-3-*O*-*β*-*D*-glucopyranosyl-(1→2)-*O*-*β*-*D*-glucopyranoside	Ⅹ	-glc (2-1) glc	-H	12
54	3*β*,12*β*-Dihydroxydammar-20(22)*E*,24-diene-6-*O*-*β*-*D*-xylopyranosyl-(1→2)-*O*-*β*-*D*-glucopyranoside	Ⅴ	-H	-*O*-glc (2-1) xyl	12

注:glc:*β*-*D*-glucopyranosyl;rha:*α*-*L*-rhamnopyranosyl;Ac:acetyl;Me:methyl.

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1.1.2 齐墩果酸型五环三萜类

与齐墩果酸型皂苷相关的红参成分研究较少,如图4、表4所示。运用LC-MS/MSn技术对比红参水提取物发现红参水煎液物的正丁醇萃取物中可能存在化合物人参皂苷Ro-6′-丁酯(**57**),竹节参苷IVa丁酯(**59**),姜状三七苷R_1-6′-丁酯(**61**)。

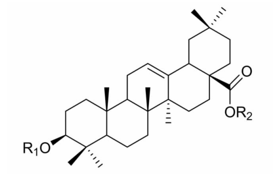

图4 齐墩果酸型皂苷结构图

Fig. 4 The structures of oleanolicacid saponins

表4 齐墩果酸型皂苷名称表

Table 4 Name of oleanolicacid saponins

序号 No.	化合物名称 Compound name	取代基 Substituent		参考文献 Ref.
		R_1	R_2	
55	Ginsenoside Ro	-glcUA (2-1) glc	-glc	9,12-14
56	Ginsenoside Ro methyl ester	-(6′-Me) glcUA (2-1) glc	-glc	12
57	Ginsenoside-Ro-6′-butyl ester	-glcUA(6′-Bu) (2-1)-glc	-glc	12,17
58	Chikusetsusaponin IVa methyl ester	-glcUA(6′-Me)	-glc	12
59	Chikusetsusaponin IVa butyl ester	-glcUA(6′-Bu)	-glc	12
60	Zingibroside R_1-6′-methyl ester	-glcUA(6′-Me) (2-1)-glc	H	12
61	Zingibroside R_1-6′-butyl ester	-glcUA(6′-Bu) (2-1)-glc	H	12
62	Polyacetyleneginsenoside Ro	-(6′-PAE) glcUA (2-1) glc	-glc	12

注:glc:*β-D*-Glucopyranosyl;glcUA:*β-D*-Glucopyranosiduronic acid;6′-Me:6′-Methylester;6′-Bu:6′-Butylester;6′-PAE:6′-Panaxytriol ester.

1.2 挥发油类

挥发油中主要含有萜类、芳香族化合物及其含氧衍生物如醇、醛、酸、酯等成分,其化学性质不稳定,易在蒸制过程损失或发生转变,从而使红参形成特有的挥发性成分,如人参炔醇、人参炔二醇、人参炔三醇[21]等。亦有Wang等[22]运用气相色谱-质谱联用(GC-MS/MS)法检测出红参中所含部分挥发性成分含量可达到鲜参的3倍以上,并得到了4种红参的特有成分7-*epi*-*cis*-sesquisabinene(**88**)、farnesene(**94**)、new ginseng terpene alcohols(**100**)、globulol(**106**)。Chen[23]利用超临界CO_2萃取分离鉴定红参挥发油成分26个,部分含量较高的成分排序:9,12-十八碳二烯酸(**116**)>3,7,11-三甲基-1,6,10-十二碳三烯(**86**)>β-谷甾醇(**103**)>镰叶芹醇(**107**)>十六烷酸(**115**),并首次分离出9,12-十八碳二烯-1-醇(**104**)、3,7,11-三甲基-2,6,10-十二碳三烯-1-醇(**105**)、维生素E(**136**)。Su等[24]自红参独参汤中分离鉴定了亚油酸等5种脂肪酸及酯类化合物(**115**、**119**~**122**)。作者结合人参、红参等挥发性成分、脂溶性成分的研究报道,整理红参中所含挥发油成分如表5、图5所示。

表5 红参的挥发油成分

Table 5 Components from volatile oil of GRRR

类型 Type	序号 No.	化合物名称 Compound name	参考文献 Ref.
烃类 Hydrocarbons	**63**	3-Methylhexadecane	23
	64	2-Methylheptadecane	23,25
	65	Icosane	23,25
	66	Hexacosane	23,25
	67	2,6,10-Trimethyldodecane	25
	68	2-Methyltridecane	25
	69	Tetradecane	25

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续表 5(Continued Tab. 5)

类型 Type	序号 No.	化合物名称 Compound name	参考文献 Ref.
	70	Pentadecane	25
	71	2-Methylpentadecane	25
	72	2,6,10,14-Tetramethylpentadecane	25
	73	Hexadecane	25
	74	7,9-Dimethylhexadecane	25
	75	2,6,10,14-Tetramethylhexadecane	25
	76	Heptadecane	25
	77	3-Methylheptadecane	25
	78	Octadecane	25
	79	Nonadecane	25
	80	1-Ethyldodecane	25
	81	1-(1,5-dimethylhexyl)-4-(4-methylpropyl)-(4-methylpropyl)-cyclohexane	25
	82	Nonadecene	25
	83	1-Icosene	25
	84	*trans*-Squalene	25
	85	1,11,13-Heptadecatriene	23
	86	3,7,11-Trimethyl-1,6,10-dodecanetriene	23
	87	3-Methylene-7,11-dimethyl-1,6,10-dodecanetriene	23
萜类 Terpenes	**88**	7-*epi*-*cis*-Sesquisabinene	22
	89	Cedrene	23
	90	Alloaromadendren	23
	91	Caryophyllene	23
	92	Patchoulene	23
	93	γ-Elemene	23
	94	α-Farnesene	23,22
	95	Neoclovene	23
	96	Germacrene	23
	97	Calarene	25
	98	Selinene	25
	99	Bicyclogammaene	25
醇类 Alcohols	**100**	New ginseng terpene alcohols	22
	101	Espatulenol	23
	102	Stigmasterol	23
	103	β-Sitosterol	23
	104	9,12-Octadecadien-1-ol	23
	105	3,7,11-Trimethyl-2,6,10-dodecatrien-1-ol	23
	106	Globulol	22,25
	107	Panaxynol(Falcarinol)	21
	108	Panaxyndol	21

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续表 5(Continued Tab. 5)

类型 Type	序号 No.	化合物名称 Compound name	参考文献 Ref.
	109	Panaxyntriol	21
	110	Spathulenol	25
	111	Ledol	25
	112	γ-Sitosterol	25
	113	Viridiflorol	25
	114	(*R*)-(-)-14-Methyl-8-hexadecyn-1-ol	25
脂肪酸及酯类 Fatty acids and Esters	**115**	Palmitic acid	23-25
	116	9,12-Octadecadienoic acid	23
	117	9,12,15-Octadecadienoic acid	23
	118	10,12-Hexadecadien-1-olacetic acid	23
	119	Linoleic acid	24,25
	120	Lauric acid	24
	121	*cis*-Hexadecenoic acid	24
	122	*cis*-Octadecenoic acid	24
	123	Elaidic acid	25
	124	Methyl linoleate	25
	125	Methyl hexadecanoate	25
	126	Octadecynoic acid	25
	127	Dibutyl phthalate	25
	128	Diisobutyl phthalate	25
	129	Di(2-ethylhexyl) phthalate	25
	130	13-Tetradecene-1-ol acetate	25
	131	Butyl 9,12-octadecadienoate	25
	132	Methyl10,13-octadecadienoate	25
酮类 Ketones	**133**	**2**-Hydroxycyclopentadecanone	**25**
醛类 Aldehydes	**134**	9,17-Octadecadienal	25
酸酐类 Anhydrides	**135**	Dodecenyl succinicanhydride	25
酚类及杂环类 Phenols and Heterocycles	**136**	Vitamin E	23
	137	Tocopherol	25
	138	Methyleugenol	25
	139	5-Allyl-1,2,3-trimethoxybenzene	25
	140	2,4,5-Trimethoxy-1-propenylbenzene	25
	141	2,2′-Methylenebis-(1,1-dimethylethyl)-4-ethylphenol	25
	142	(1a*R*)-1aβ,2,3,3a,4,5,6,7bβ-Octahydro-1,1,3aβ,7-tetramethyl-1H-cyclopropylnaphthalene	25
	143	1,2,3,5,6,7,8,8a-Octahydro-1,8a-dimethyl-7-(1-methylvinyl)-[1*S*-(1α,7α,8aα)] naphthalene	25

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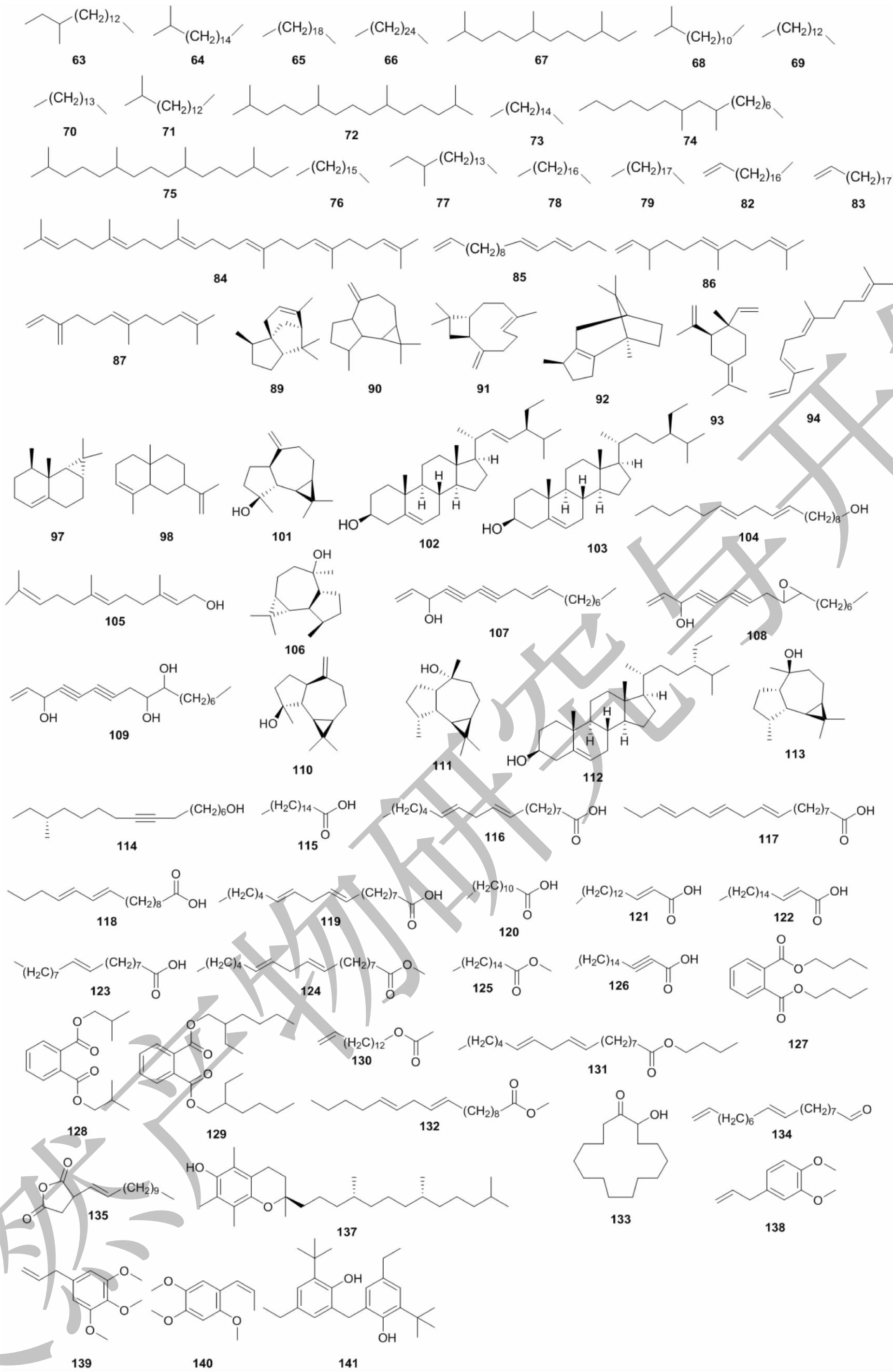

图5　红参挥发油成分的结构

Fig. 5　The structures of volatile oil of GRRR

1.3　糖类

红参中主要含有多糖、还原糖、低聚糖、单糖等。Qiao[26]对比生晒参、红参及黑参的总含糖量发现，加工流程越长，总糖损失的越多。鲜参在高温蒸制成红参后，多糖、低聚糖含量减少，单糖（果糖、葡萄糖）随之增加[27,28]。红参酸性多糖（RGAP）为红参的活性成分之一，具有免疫调节作用[29]。

1.4　氨基酸类

1.4.1　精氨酸双糖苷（arginyl-fructosyl-glucose，AFG）、精氨酸单糖苷（arginyl-fructos，AF）

红参的炮制过程中氨基酸种类基本不变，但易造成氨基酸损失，以精氨酸（Arg）损失最多，这是由

于精氨酸与麦芽糖或葡萄糖进一步发生梅拉德反应(Maillard reaction),并生成中间产物精氨酸单糖苷、精氨酸双糖苷,其主要形成于红参的第一次烘干阶段,适当升高温度、延长时间能促使精氨酸减少[30,31]。Zheng 等[32]运用聚丙烯酰胺柱层析对红参水煎液进行分析,首次发现并鉴定了精氨酸双糖苷的结构(如图 6 所示),其结构为 1-(精氨酸-N^{α}基)-1-去氧-4-*O*-(*α*-*D*-吡喃葡萄糖基)-*D*-果糖(1-N^{α}-arginine-1-deoxy-4-*O*-(*α*-*D*-glucopyranosyl)-*D*-fructose),分子式为 $C_{18}H_{34}N_4O_{12}$,分子量为 498.482。现代研究证明精氨酸双糖苷具有促进微循环、抗氧化、抗疲劳、增强免疫功能等药理活性[33,34]。

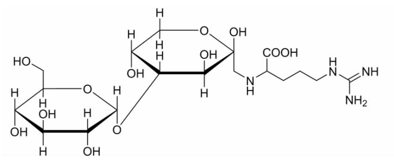

图 6 精氨酸双糖苷结构图

Fig. 6 The structures of arginyl-fructosyl-glucose

1.4.2 田七素

田七素是在人参、三七、西洋参中广泛存在的一种特殊氨基酸,有一定的神经毒作用。Sun 等[35]发现红参在炮制中田七素的含量可降低近一半。因此红参相较于人参等具有毒性小、安全有效等优点。

1.5 麦芽酚及其葡萄糖苷

在红参炮制过程中,麦芽糖与氨基酸发生梅拉德反应从而生成麦芽酚。麦芽酚是红参的特有成分,其结构为 3-羟基-2-甲基-4-吡喃酮(如图 7 所示)[36],可增加红参的香气。学者们亦在研究中逐渐从中国红参中分离鉴定出麦芽酚葡萄糖苷[37]、异麦芽酚甘露糖苷[38]。

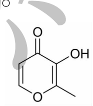

图 7 麦芽酚结构图

Fig. 7 The structures of maltol

1.6 微量元素

红参中的微量元素含量十分丰富,包含人体必需、可能必需及潜在毒性的元素。Guo 等[39]利用电感耦合等离子体发射质谱法(ICP-MS)测定红参中锰、铜、锌、钡、钴、铁、镍、镉 8 种微量元素的含量,并验证该法用于测量红参中微量元素的有效性。

2 红参的药理活性

2.1 增强免疫及抗肿瘤

蒸制之法会使红参生成一些稀有成分或特有成分,使其具有显著的抗肿瘤活性[40]。研究发现红参中人参总皂苷、人参单体皂苷 Rb_1、Rd、Rh_1、Rh_2、Rg_3、CK 及红参酸性多糖可增强免疫功能[41]。亦有研究证明人参皂苷 Rg_3 与阿帕替尼[42]可协同增强抗癌活性。目前,对稀有皂苷 Rg_3 抗肿瘤作用的研究已有较为完善的综述[43,44],故在此佐证红参其他成分的抗肿瘤作用。Liu[45]通过对食管鳞癌细胞的体外培养及裸鼠体内接种,发现人参皂苷 Rk_3 可抑制裸鼠体内肿瘤生长、抑制食管癌细胞 Eca109 和 KYSE150 的增殖等发挥抗癌活性。Chen 等[46]发现人参皂苷 CK 可以抑制骨肉瘤细胞的存活和增殖,具有明显的抗肿瘤作用。另有研究发现人参皂苷 Rk_1、人参皂苷 Rg_5 可抑制乳腺癌细胞的增殖[47,48]。Li 等[49]研究发现红参多糖可抑制白细胞数减少症、增强 NK 细胞(natural killer cell)活性,白细胞介素-2(interleukin-2,IL-2)活性对红参多糖具有剂量依赖性,浓度愈高,活性愈强,但当红参多糖浓度到达一定程度,IL-2 活性会有所下降。

2.2 抗氧化

在生物体系中,自由基缺少配对电子,便会结合体内分子的电子,从而对人体、动物体中的细胞或组织造成损伤。超氧化物歧化酶(superoxide dismutase,SOD)可平衡体内氧化环境,减少自由基对人体的损伤。Li 等[50]通过建立过氧化氢(H_2O_2)诱导 H9c2 大鼠心肌细胞体外心肌细胞氧化应激损伤模型,检测到在细胞水平上红参提取物可抑制乳酸脱氢酶(lactate dehydrogenase,LDH)、丙二醛(malondialdehyde,MDA)的释放,提高 SOD 的活性及 Bcl-2/Bax 的比值,从而减轻 H_2O_2 诱导的氧化应激损伤、减少大鼠心肌细胞凋亡。红参在小鼠体内发挥抗氧化活性,Liu 等[51]发现红参多糖(RGPs)可明显提高谷胱甘肽过氧化物酶(glutathione peroxidase,GSH-Px)和 SOD 的水平,减少血清及各组织中自由基氧化产物 MDA 的含量以减轻对机体的损伤。Yu 等[52]以维生素 C 为阳性对照,对比不同浓度的红参多糖,发现 80% 的红参多糖醇提液抗氧化作用最强。Jin 等[53]运用流式细胞术测得红参中的人参皂苷 Rg_3 可改善 1-甲基-4-苯基吡啶离子诱导的神经

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细胞应激损伤。以上文献均表明红参在一定程度上具有清除自由基(如:DPPH 自由基、羟自由基)、抗氧化的药理活性。

2.3 抗衰老

Zeng 等[54]发现红参提取物对衰老小鼠模型有明显的保护作用,其机制可能与机体免疫功能增强、自由基清除等有关。Liu[55]通过延长黑腹果蝇生命周期实验发现机体内 SOD 和 MDA 的含量可影响衰老程度。Hou 等[56]研究发现红参在部分浓度下可明显延长雌性黑腹果蝇的寿命。此外,长期服用红参也可以减轻由正常衰老引起的认知缺陷。[57]

2.4 抗疲劳

Huang 等[58]对红参中精氨酸双糖苷进行小鼠抗疲劳实验,发现该成分可明显增加小鼠强迫性游泳的时间,证明精氨酸双糖苷具有抗疲劳能力。Huang[59]研究对比平性参、生晒参、红参对小鼠的抗疲劳作用,以平性参效果最为显著,而红参的效果最小。

2.5 抗糖尿病

糖尿病为临床常见慢性代谢性疾病之一,分为 1 型糖尿病和 2 型糖尿病。中医称其消渴病,主要表现为“三多一少”,即多食、多饮、多尿,消瘦,并伴有高血糖、高血脂、动脉粥样硬化等并发症。Qi 等[60]发现经^{60}Co-γ 辐照的红参提取物降低 1 型糖尿病小鼠血糖作用显著,并测得与常用降糖药二甲双胍效果近似的 15kGy 高剂量辐照红参皂苷提取物可降低小鼠血清 TC 含量、缓解小鼠内脏损伤。Li 等[61]发现红参中的人参皂苷 CK 或红参多糖和人参皂苷 Rb_1 具有明显降血糖作用,并能改善大鼠状态。Li 等[62]验证了红参可显著降低高脂大鼠模型的甘油三酯(triglyceride, TC)、高密度胆固醇(high-density lipoprotein cholesterol, HDL-C),提高低密度胆固醇(low-density lipoprotein cholesterol, LDL-C)的水平,且测定喂养高脂红参饲料大鼠的动脉粥样硬化指数(AI)明显低于高脂模型组。Kim 等[63]研究亦发现由果胶裂解酶修饰的红参提取物 GS-E3D 可改善脂肪外膜外组织的胰岛素敏感性及与肥胖相关的糖耐量受损。

2.6 抗肝肾毒性

Han[64]深入研究麦芽酚对小鼠肝、肾损伤的影响,通过检测生化指标及病理标本研究麦芽酚可能通过抗氧化、抗炎等作用减轻小鼠酒精性肝损伤及对乙酰氨基酚所致肝损伤,抑制顺铂诱导的肾小管细胞的坏死和凋亡。Huang 等[65]测得环翠楼高丽红参的复方制剂可降低小鼠眼球谷丙转氨酶(alanine aminotransferase, ALT)、谷草转氨酶(aspartate aminotransferase, AST)活性及小鼠肝脏 MDA 含量,以减轻小鼠的酒精性肝损伤。

2.7 其他作用

Han 等[66]综合整理红参和发酵人参中人参皂苷的抗过敏作用(如治疗哮喘、过敏性鼻炎、皮肤瘙痒等症)研究,并阐述相应的抗过敏机制。Hou 等[67]测定红参醇提物中的人参炔醇、人参炔二醇能有效地控制因细菌感染引起的痤疮。Park 等[68]发现红参中的人参皂苷 Rd、Re、Rb_1 具有抗肥胖作用,其能明显降低高脂肪大鼠的体脂质量和体重。

3 结语

通过检索整理近十年的文献发现,对红参中化学成分的研究报道以皂苷类居多,特别是对稀有皂苷化学成分及药理活性的研究;对非皂苷类成分红参多糖、麦芽酚、精氨酸双糖苷等研究也较为完善;红参中亦含有少量蛋白,但现今对红参蛋白的研究较少。现代研究红参的药理活性主要体现在抗免疫、抗肿瘤、抗氧化、抗糖尿病,抗衰老、抗肝肾毒性作用与红参的抗氧化作用联系密切,其亦有抗过敏、抗粉刺、抗肥胖等作用。

在新技术的影响下,红参中更多的成分有待发现,如 Xu 等[69]运用超高效液相色谱-四级杆-飞行时间串联质谱(UHPLC-Q-TOF/MS)法分析红参醇提液中发现并推测红参中可能存在糖基乙酰化产物。同时,利用新技术对红参商品的快速检测也成为研究热点之一。市售红参出现软、黏现象,多因加工中掺糖导致,Ying 等[70]采用近红外光谱技术建立模型可快速验证红参糖分是否超标,亦有研究通过对比不同批次的红参拟定红参中总还原糖限度[71,72],为红参的质量检测提供依据。由此可见对于红参化学成分和药理活性的探索还需继续深入。

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