

## Электронный дополнительный материал

УДК 582.948.2:615.252.349.7]-004.94

### ИССЛЕДОВАНИЕ ГИПОГЛИКЕМИЧЕСКОЙ АКТИВНОСТИ ИЗВЛЕЧЕНИЙ ИЗ РАСТЕНИЙ СЕМЕЙСТВА BORAGINACEAE МЕТОДАМИ «*IN SILICO*» И «*IN VIVO*»\*

© В.В. Величко<sup>1\*\*</sup>, Е.Д. Олешко<sup>1</sup>, Д.С. Круглов<sup>1</sup>, В.Г. Лужанин<sup>2</sup>, Д.С. Ивкин<sup>3</sup>, В.Е. Ковансков<sup>3</sup>,  
Н.С. Ионов<sup>4</sup>, Д.А. Филимонов<sup>4</sup>, А.А. Лагунин<sup>4</sup>, В.В. Поройков<sup>4</sup>, Д.Н. Оленников<sup>5</sup>

<sup>1</sup> Новосибирский государственный медицинский университет, Красный пр., 52,  
Новосибирск, 630091, Россия, velichkvik@rambler.ru

<sup>2</sup> Пермская государственная фармацевтическая академия, Екатеринбургская ул.,  
110, Пермь, 614990, Россия

<sup>3</sup> Санкт-Петербургский государственный химико-фармацевтический  
университет, ул. Профессора Попова, 14А, Санкт-Петербург, 197022, Россия

<sup>4</sup> Научно-исследовательский институт биомедицинской химии имени  
В.Н. Ореховича, ул. Погодинская, 10/8, Москва, 119121, Россия

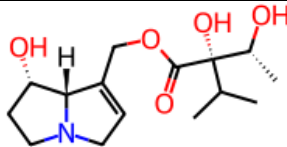
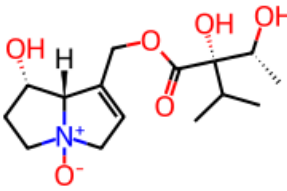
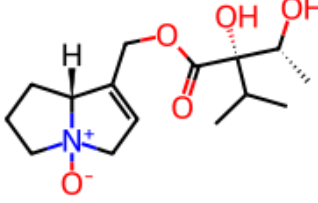
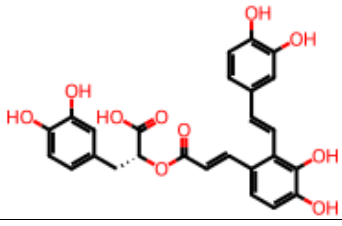
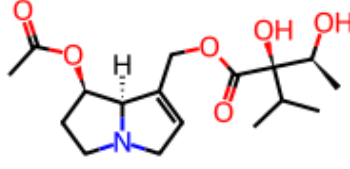
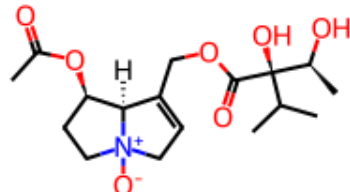
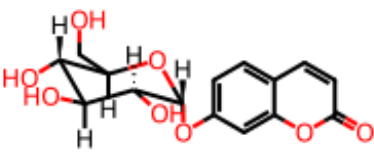
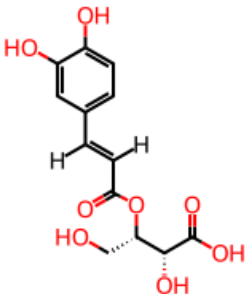
<sup>5</sup> Институт общей и экспериментальной биологии СО РАН, ул. Сахьяновой, 6,  
Улан-Удэ, 670047, Россия

---

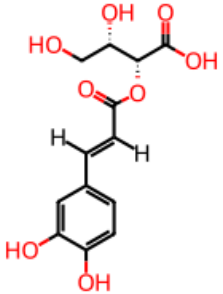
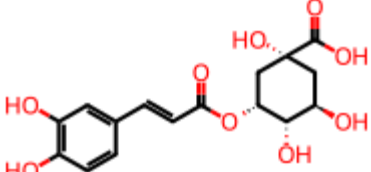
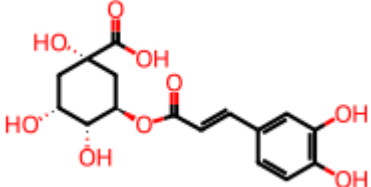
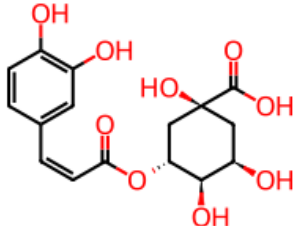
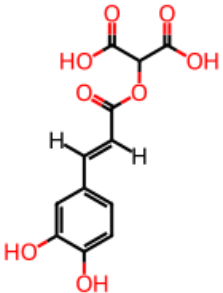
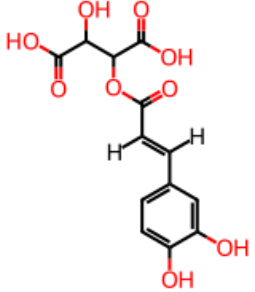
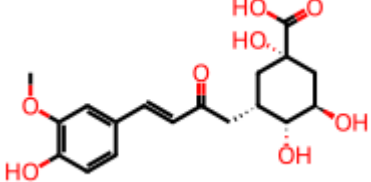
\* Полный текст статьи опубликован: Величко В.В., Олешко Е.Д., Круглов Д.С., Лужанин В.Г., Ивкин Д.С., Ковансков В.Е., Ионов Н.С., Филимонов Д.А., Лагунин А.А., Поройков В.В., Оленников Д.Н. Исследование гипогликемической активности извлечений из растений семейства *Boraginaceae* методами «*in silico*» и «*in vivo*» // Химия растительного сырья. 2026. №2. С. 436–448. <https://doi.org/10.14258/jcprm.20260217869>.

\*\* Автор, с которым следует вести переписку.

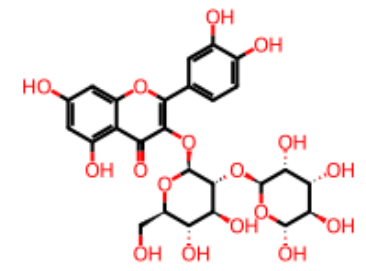
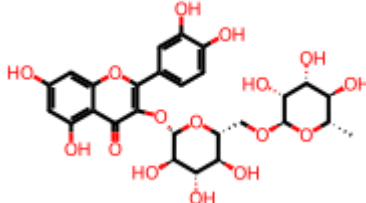
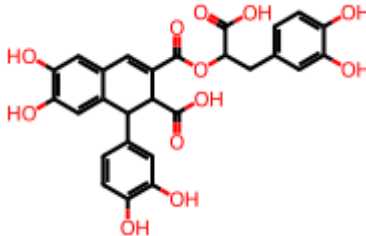
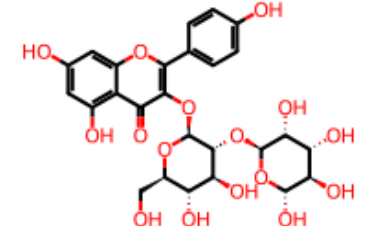
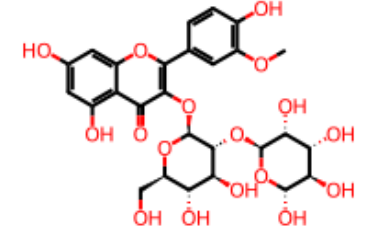
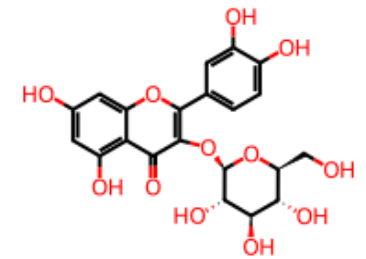
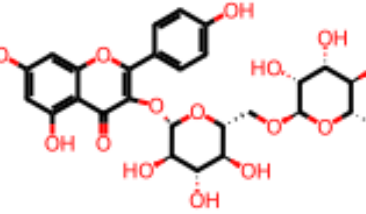
## Сравнение фитохимического состава изучаемых образцов

№	Химическое название	Образец	Структурная формула
1	2	3	4
1	lycopsamine	G1, G4	
2	lycopsamine n-oxide	G1, G3, G4	
3	viridiflorin N-oxide	G1	
4	salvianolic acid A	G1, G2, G3	
5	lycopsamine 7-O-acetate	G1	
6	7-O-Acetyllycopsamine N-oxide	G1	
7	umbelliferone O-glucoside	G1	
8	3-O-caffeoyl threonic acid	G1, G2, G3, G4	

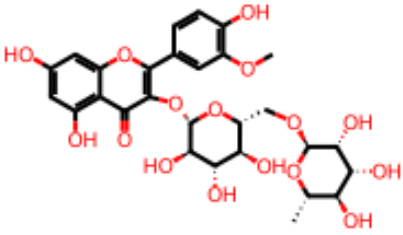
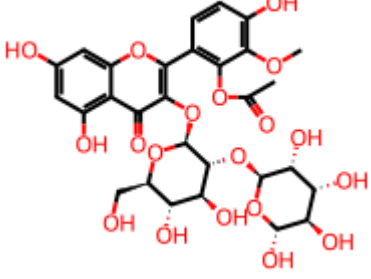
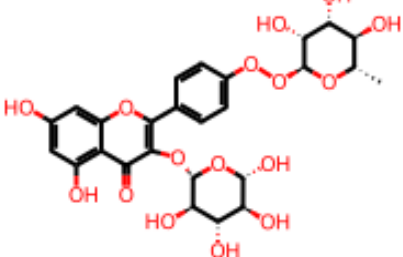
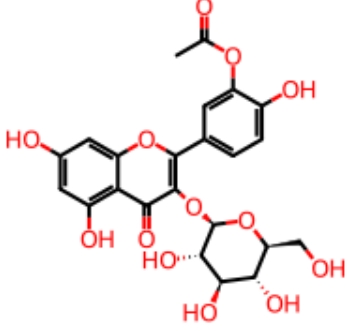
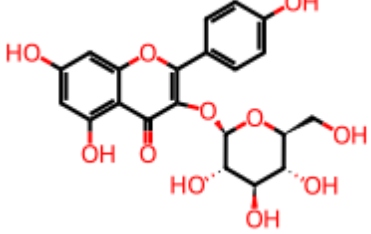
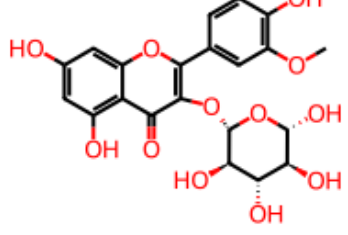
Продолжение таблицы

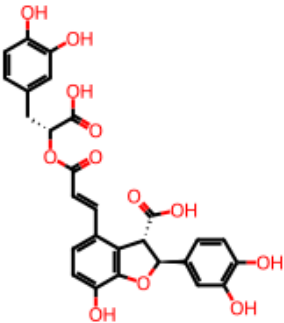
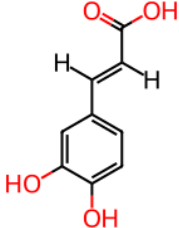
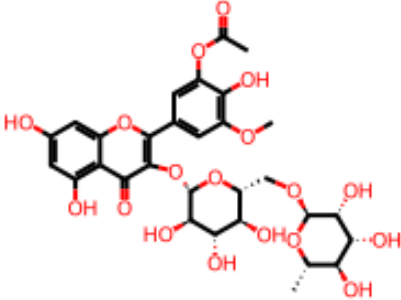
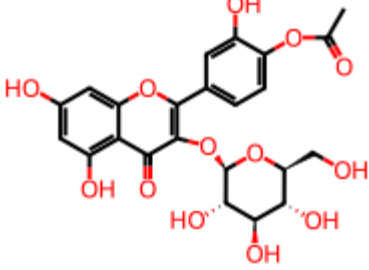
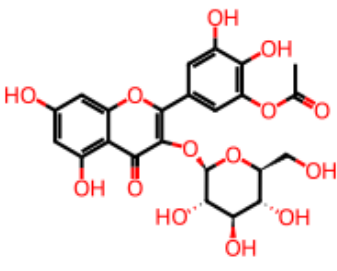
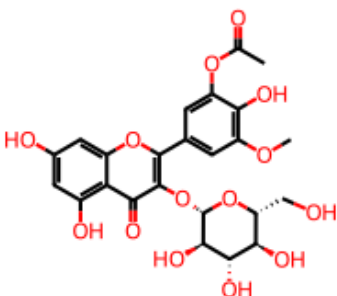
1	2	3	4
9	2-O-caffeoyl threonic acid	G1, G2, G3, G4	 <p>The structure shows a threonic acid moiety (a four-carbon chain with hydroxyl groups at C2 and C3, and a carboxylic acid group at C4) linked via an ester bond to the 2-position of a caffeoyl group (a propenoic acid derivative with two hydroxyl groups on the benzene ring).</p>
10	5-O-caffeoylquinic acid, trans-	G1	 <p>The structure shows a trans-caffeoyl group (a propenoic acid derivative with two hydroxyl groups on the benzene ring) linked via an ester bond to the 5-position of a quinic acid moiety (a cyclohexane ring with hydroxyl groups at C1, C2, C3, and C4, and a carboxylic acid group at C6).</p>
11	3-O-caffeoylquinic acid, trans-	G1	 <p>The structure shows a trans-caffeoyl group (a propenoic acid derivative with two hydroxyl groups on the benzene ring) linked via an ester bond to the 3-position of a quinic acid moiety (a cyclohexane ring with hydroxyl groups at C1, C2, C4, and C5, and a carboxylic acid group at C6).</p>
12	5-O-caffeoylquinic acid, cis-	G1	 <p>The structure shows a cis-caffeoyl group (a propenoic acid derivative with two hydroxyl groups on the benzene ring) linked via an ester bond to the 5-position of a quinic acid moiety (a cyclohexane ring with hydroxyl groups at C1, C2, C3, and C4, and a carboxylic acid group at C6).</p>
13	2-O-caffeoyl-tartronic acid	G1	 <p>The structure shows a tartronic acid moiety (a four-carbon chain with hydroxyl groups at C2 and C3, and carboxylic acid groups at C1 and C4) linked via an ester bond to the 2-position of a caffeoyl group (a propenoic acid derivative with two hydroxyl groups on the benzene ring).</p>
14	caftaric acid	G1	 <p>The structure shows a caftaric acid moiety (a four-carbon chain with hydroxyl groups at C2 and C3, and carboxylic acid groups at C1 and C4) linked via an ester bond to the 2-position of a caffeoyl group (a propenoic acid derivative with two hydroxyl groups on the benzene ring).</p>
15	5-O-feruloylquinic acid	G1	 <p>The structure shows a feruloyl group (a propenoic acid derivative with a methoxy group and a hydroxyl group on the benzene ring) linked via an ester bond to the 5-position of a quinic acid moiety (a cyclohexane ring with hydroxyl groups at C1, C2, C3, and C4, and a carboxylic acid group at C6).</p>

Продолжение таблицы

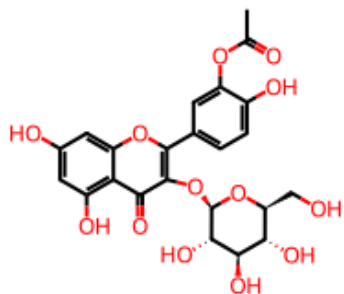
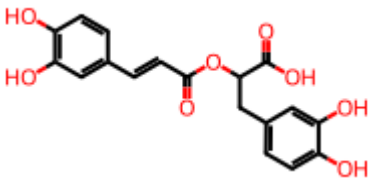
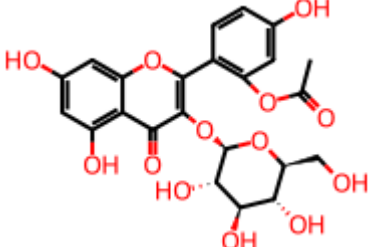
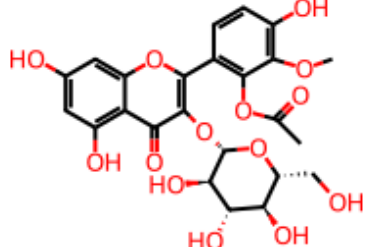
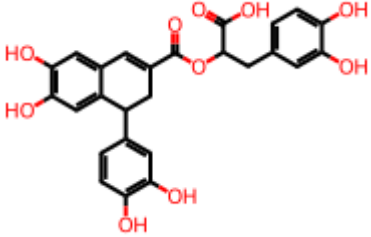
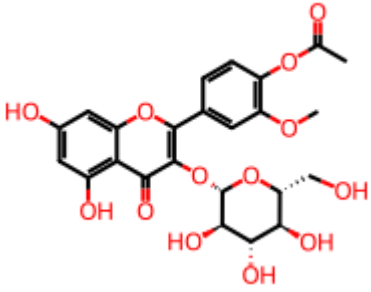
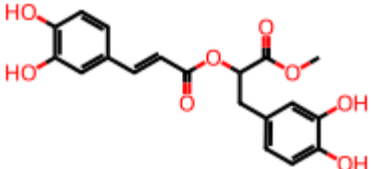
1	2	3	4
16	quercetin 3-O-neohesperidoside	G1, G4	 <p>The structure shows a quercetin aglycone (a flavonol with hydroxyl groups at positions 3, 5, 7, and 3', 4', and 5') linked via an ether bond at the 3-position to a neohesperidose disaccharide (6-O-α-D-glucopyranosyl-β-D-fructofuranose).</p>
17	quercetin 3-O-rutinoside	G1, G2, G3, G4	 <p>The structure shows a quercetin aglycone linked via an ether bond at the 3-position to a rutinoside disaccharide (6-O-α-D-glucopyranosyl-β-D-glucopyranose).</p>
18	globoidnan B	G1, G2, G3, G4	 <p>The structure shows a complex polyphenolic aglycone with multiple hydroxyl groups and a central ether bridge, linked to a disaccharide moiety.</p>
19	kaempferol 3-O-neohesperidoside	G1, G2, G3, G4	 <p>The structure shows a kaempferol aglycone (hydroxyl groups at positions 5, 7, and 3', 4') linked via an ether bond at the 3-position to a neohesperidose disaccharide.</p>
20	isoramnetin 3-O-neohesperidoside	G1	 <p>The structure shows an isoramnetin aglycone (hydroxyl groups at positions 5, 7, and 3', 4') linked via an ether bond at the 3-position to a neohesperidose disaccharide.</p>
21	quercetin 3-O-glucoside	G1, G4	 <p>The structure shows a quercetin aglycone linked via an ether bond at the 3-position to a glucose molecule.</p>
22	kaempferol 3-O-rutinoside	G1, G2, G3, G4	 <p>The structure shows a kaempferol aglycone linked via an ether bond at the 3-position to a rutinoside disaccharide.</p>

Продолжение таблицы

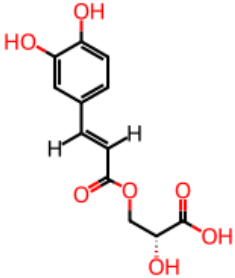
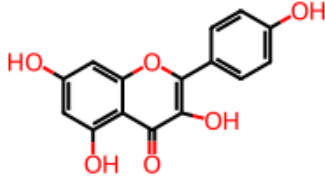
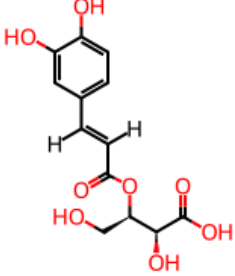
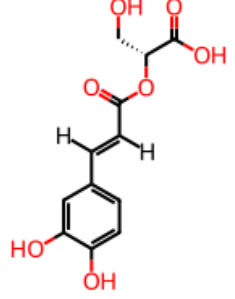
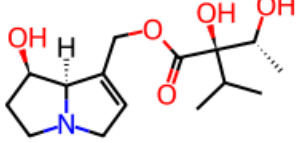
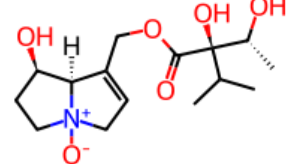
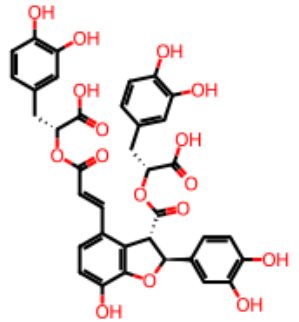
1	2	3	4
23	isoramnetin 3-O-rutinoside	G1	 <p>The structure shows a flavone core (isoramnetin) with a rutinoside moiety attached at the 3-position. The rutinoside consists of a glucose unit linked to a rhamnose unit.</p>
24	isoramnetin 3-O-(6''-O-acetyl)-neohesperidoside	G1	 <p>The structure shows a flavone core (isoramnetin) with a neohesperidoside moiety attached at the 3-position. The neohesperidoside consists of a glucose unit linked to a rhamnose unit, which has an acetyl group at the 6'' position.</p>
25	kaempferol 3-O-(4''-O-rhamnosyl)-glucoside	G1	 <p>The structure shows a flavone core (kaempferol) with a rhamnosyl-glucoside moiety attached at the 3-position. The rhamnosyl group is attached to the glucose unit at the 4'' position.</p>
26	quercetin 3-O-(2''-O-acetyl)-glucoside	G1, G4	 <p>The structure shows a flavone core (quercetin) with a 2''-O-acetyl-glucoside moiety attached at the 3-position. The acetyl group is attached to the glucose unit at the 2'' position.</p>
27	kaempferol 3-O-glucoside	G1, G4	 <p>The structure shows a flavone core (kaempferol) with a glucose moiety attached at the 3-position.</p>
28	isoramnetin 3-O-glucoside	G1	 <p>The structure shows a flavone core (isoramnetin) with a glucose moiety attached at the 3-position.</p>

1	2	3	4
29	lithospermic acid B	G1, G2	 <p>The structure shows a central chromone ring system. At position 2, there is a propyl chain ending in a p-coumaroyl group. At position 3, there is a propyl chain ending in a propionic acid group. At position 4, there is a p-coumaroyl group. The coumaroyl groups are shown with their respective hydroxyl groups in red.</p>
30	Caffeic Acid	G1, G2, G3, G4	 <p>The structure shows a benzene ring with hydroxyl groups at positions 3 and 4. At position 1, there is a propenoic acid side chain. The hydroxyl groups and the propenoic acid group are shown in red.</p>
31	isoramnetin 3-O-(2''-O-acetyl)-rutinoside	G1	 <p>The structure shows a flavone core (isoramnetin) with a rutinoside group at position 3. The rutinoside is composed of a glucose unit linked to a rhamnose unit. An acetyl group is attached to the 2'' position of the rhamnose unit. The hydroxyl groups and acetyl group are shown in red.</p>
32	quercetin 3-O-(3''-O-acetyl)-glucoside	G1, G2, G3	 <p>The structure shows a flavone core (quercetin) with a glucoside group at position 3. The glucose unit has an acetyl group at the 3'' position. The hydroxyl groups and acetyl group are shown in red.</p>
33	quercetin 3-O-(4''-O-acetyl)-glucoside	G1, G2, G3	 <p>The structure shows a flavone core (quercetin) with a glucoside group at position 3. The glucose unit has an acetyl group at the 4'' position. The hydroxyl groups and acetyl group are shown in red.</p>
34	isoramnetin 3-O-(2''-O-acetyl)-glucoside	G1	 <p>The structure shows a flavone core (isoramnetin) with a glucoside group at position 3. The glucose unit has an acetyl group at the 2'' position. The hydroxyl groups and acetyl group are shown in red.</p>

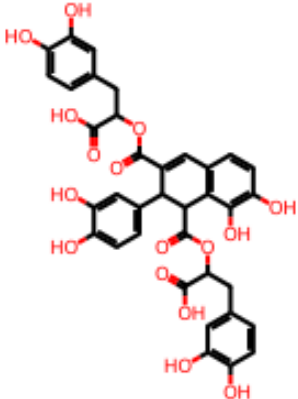
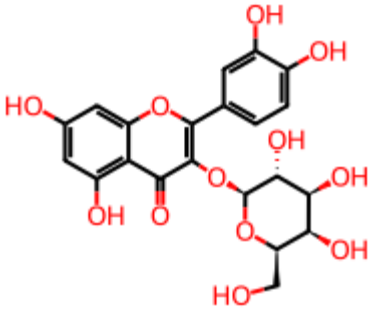
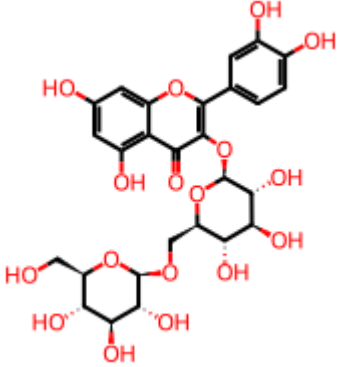
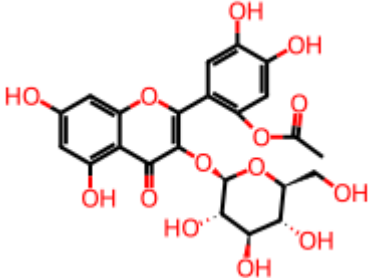
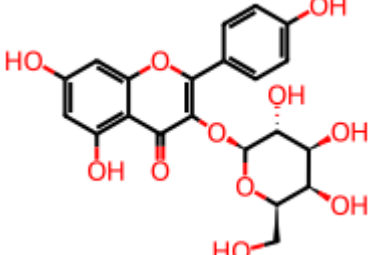
Продолжение таблицы

1	2	3	4
35	kaempferol 3-O-(2''-O-acetyl)-glucoside	G1	
36	rosmarinic acid	G1, G2, G3, G4	
37	kaempferol 3-O-(6''-O-acetyl)-glucoside	G1, G2, G3	
38	isoramnetin 3-O-(6''-O-acetyl)-glucoside	G1	
39	globoidnan A	G1, G3	
40	isoramnetin 3-O-(4''-O-acetyl)-glucoside	G1	
41	rosmarinic acid methyl ester	G1, G2, G3	

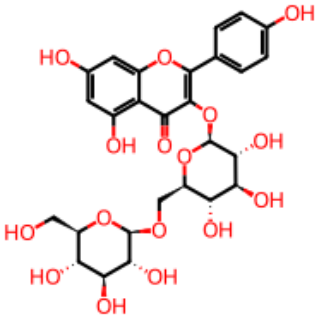
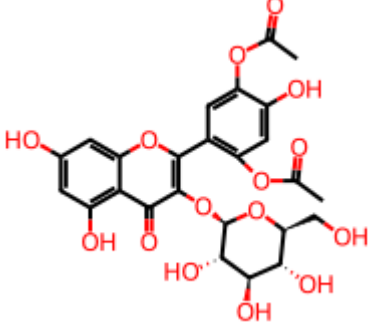
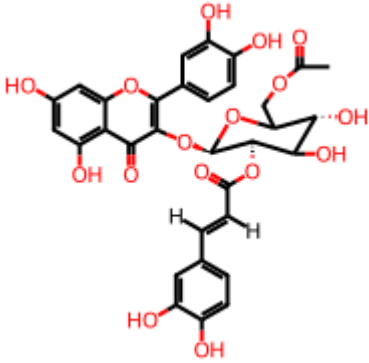
Продолжение таблицы

1	2	3	4
42	3-O-caffeoyl-glyceric acid	G2, G3, G4	 <p>The structure shows a caffeoyl group (a benzene ring with hydroxyl groups at the 3 and 4 positions) attached to the 3rd carbon of a glyceric acid chain. The glyceric acid chain has hydroxyl groups at the 2nd and 3rd carbons.</p>
43	kaempferol	G2	 <p>The structure is a flavone aglycone consisting of a chromone core with hydroxyl groups at the 5, 7, and 8 positions, and a 4-hydroxyphenyl group at the 3-position.</p>
44	caffeoyl threonic acid isomer	G3	 <p>The structure shows a caffeoyl group attached to the 2nd carbon of a threonic acid chain. The threonic acid chain has hydroxyl groups at the 1st and 3rd carbons.</p>
45	2-O-caffeoyl-glyceric acid	G3, G4	 <p>The structure shows a caffeoyl group attached to the 2nd carbon of a glyceric acid chain. The glyceric acid chain has hydroxyl groups at the 1st and 3rd carbons.</p>
46	intermediate	G4	 <p>The structure shows a pyrrolidine ring system with a hydroxyl group and a hydrogen atom on the nitrogen, and a side chain containing a carboxylic acid group and two hydroxyl groups.</p>
47	intermediate n-oxide	G4	 <p>The structure is similar to the intermediate above, but the nitrogen atom is oxidized to a nitrosonium ion (N<sup>+</sup>), and there is a negatively charged oxygen atom (O<sup>-</sup>) nearby.</p>
48	salvianolic acid B	G4	 <p>The structure is a complex polyphenolic compound consisting of a central chromone core with multiple hydroxyl groups and several caffeoyl side chains attached to the 3 and 5 positions.</p>

Продолжение таблицы

1	2	3	4
49	salvianolic acid L	G4	 <p>The structure of salvianolic acid L is a complex polyphenolic compound. It features a central chromone ring system with multiple hydroxyl groups. It is substituted with several side chains, including a propyl chain with a hydroxyl group, a p-coumaroyl chain, and a galloyl chain. The galloyl chain is further substituted with a hydroxyl group and a propyl chain with a hydroxyl group.</p>
50	quercetin 3-O-galactoside	G4	 <p>The structure of quercetin 3-O-galactoside consists of a quercetin aglycone core. The quercetin core is a flavon-3-ol with hydroxyl groups at positions 2, 3, 7, and 8. The 3-OH group is glycosylated with a galactose molecule. The galactose is shown in its pyranose form with hydroxyl groups at positions 2, 3, 4, and 6.</p>
51	quercetin 3-O-gentiobioside	G4	 <p>The structure of quercetin 3-O-gentiobioside is similar to quercetin 3-O-galactoside, but the galactose is replaced by a gentiobiose molecule. Gentiobiose is a disaccharide composed of two glucose units linked by a beta-1,6-glycosidic bond. The quercetin aglycone is attached to the C1 of the terminal glucose unit.</p>
52	quercetin 3-O-(6''-O-acetyl)-glucoside	G4	 <p>The structure of quercetin 3-O-(6''-O-acetyl)-glucoside features a quercetin aglycone core. The 3-OH group is glycosylated with a glucose molecule. The glucose is in its pyranose form with hydroxyl groups at positions 2, 3, 4, and 6. An acetyl group is attached to the C6 of the glucose molecule.</p>
53	kaempferol 3-O-galactoside	G4	 <p>The structure of kaempferol 3-O-galactoside consists of a kaempferol aglycone core. The kaempferol core is a flavon-3-ol with hydroxyl groups at positions 5 and 8. The 3-OH group is glycosylated with a galactose molecule. The galactose is shown in its pyranose form with hydroxyl groups at positions 2, 3, 4, and 6.</p>

Окончание таблицы

1	2	3	4
54	kaempferol 3-O-gentiobioside	G4	 <p>The structure shows a kaempferol aglycone (a flavone with hydroxyl groups at positions 5, 7, and 8) linked at the 3-position to a gentiobioside disaccharide. The gentiobioside consists of a glucose unit linked to a galactose unit via a beta-1,6-glycosidic bond. The galactose unit is substituted at the 2-position with a hydroxyl group. The entire structure is drawn in red.</p>
55	quercetin 3-O-(2'',6''-O-acetyl)-glucoside	G4	 <p>The structure shows a quercetin aglycone (a flavone with hydroxyl groups at positions 5, 7, and 8, and a ketone at position 4) linked at the 3-position to a glucose unit. The glucose unit is substituted at the 2 and 6 positions with acetyl groups (-O-C(=O)-CH<sub>3</sub>). The entire structure is drawn in red.</p>
56	noneazide	G4	 <p>The structure shows a quercetin aglycone linked at the 3-position to a glucose unit. The glucose unit is substituted at the 2-position with a noneazide group (-O-C(=O)-CH=CH-2,4,6-trihydroxyphenyl). The entire structure is drawn in red.</p>