·综述·

云实属植物的化学成分与生物活性研究进展

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［摘要］ 查阅国内外相关文献，对 2005 年以来报道的云实属植物的化学成分及其生物活性进行综述。云实属植物中含有萜类、黄酮类、甾体等多种化学成分，具有抗病毒、抗炎、抗疟疾、抗肿瘤等生物活性。

［关键词］ 云实属；二萜化合物；生物活性

Advances in Research of Chemical Constituents and Biological Activity of Caesalpinia Plants

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［**Abstract**］ **Objective**：To summarize the chemical and pharmacological advances of genus *Ceasalpiana*（Caesalpiniaceae）since 2005. Several classes of chemical compounds，such as flavonoids，diterpenoids，and steroids，have been isolated from various species which were reported to show a wide range of pharmacological properties，including antiviral，anti-inflammatory，antitumor and antimicrobial activities.

［**Keywords**］ *Caesalpinia*；diterpenoids；biological activity
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云实属（*Caesalpinia* L.）植物约有 120 ~ 150 个物种，为一多元属（polyphyletic）。东南亚是云实亚科的一个分布中心，中国云实属植物有 20 个物种，从热带到温带地区均有分布[1]。该属植物有云实 *Caesalpinia decapetala*、苦石莲 *Caesalpinia minax* Hance、苏木 *Caesalpinia sappan* L. 入药，多作为民间用药，其根、皮、种子入药可用于治疗发热、疟疾、风湿病等病症[2]。吴兆华等[2]对 2005 年之前报道的云实属化学成分及药理作用进行综述，云实属植物部分化学成分表现出较强的体外生物活性，具有广阔的应用前景和较大的研究价值。本文对 2005 年以来有关云实属植物化学成分和生物活性方面的报道进行综述，概括了近年来云实属植物的研究概况，为其深入的研究提供参考。

1　化学成分

目前对该属植物的研究，主要报道了二萜、黄酮等化学成分。

1.1 二萜类化合物

从该属得到 140 余个二萜类化合物，主要是 cassane 二萜和 norcassane 二萜。在 *C. pulcherrima*、*C. crista*、*C. sappan*、*C. minax* 等植物中都有文献报道[3-31]，结构式如图 1 所示。

1.2 黄酮类化合物

在 *C. pulcherrima*、*C. millettii* Hook.、*C. digyna* Rottler 等植物中均发现了黄酮类化合物[32-41]，结构式如图 2 所示。

1.3 其他

除了二萜类和黄酮类化学成分，在该属植物也发现了其他类型的化合物[28,42-48]，结构式如图 3 所示。

2　生物活性

2.1 抗炎、抗氧化活性

Min 等[35] 从 *C. sappan* L 分离得到化学成分 protosappanin A、3-deoxysappanchalcone，以 RAW264.7

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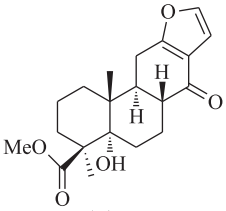
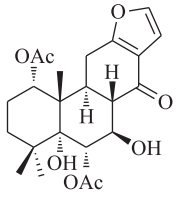

Norcaesalpin D 1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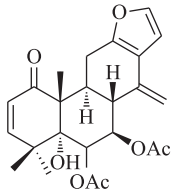
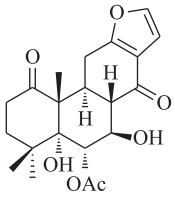

caesalpinins 3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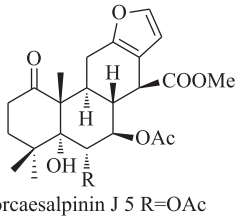
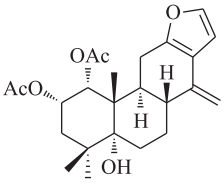

norcaesalpinin J 5 R=OAc
caesalpines B 6 R=H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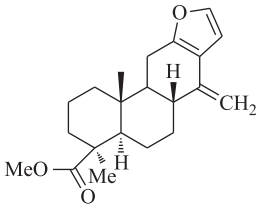
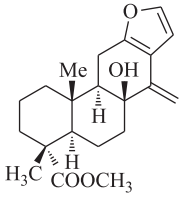
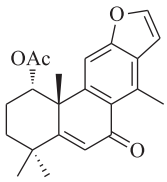

benthaminin 2 8


mimosol A 9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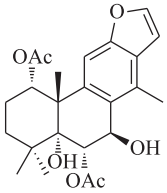
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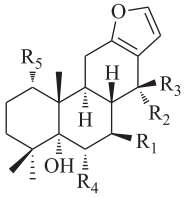
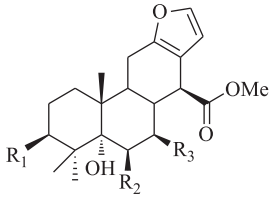
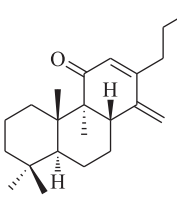
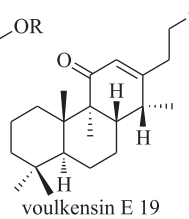
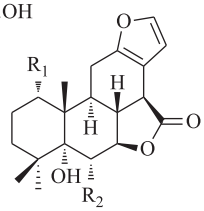
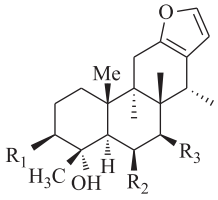

caesalpinins K 12 R_1=OH;R_2=Me;R_3=R_4=H;R_5=OAc
caesalpinins L 13 R_1=R_5=OAc;R_2=OH;R_3=Me;R_4==H
caesalpinins M 14 R_1=R_5=OAc;R_2=COOMe;R_3=H;R_4=OH
caesalpinins N 15 R_1=OH;R_2=R4=H;R_3=CHO;R_5=OAc
caesalpines A 36 R_1=OAc;R_2=R4=H;R_3=COOMe;R_5=OH

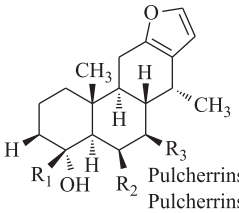

R_1=OCOPh;R_2=OH;R_3=OAc
pulcherrin C 16-3

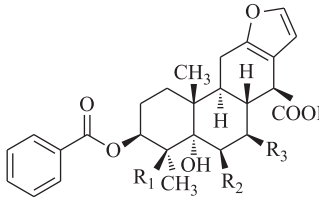

voulkensin C 17 R=Caffeoy l
voulkensin D 18 R=H

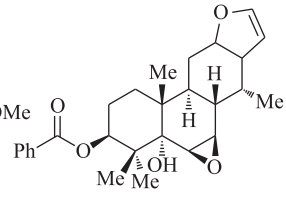

voulkensin E 19

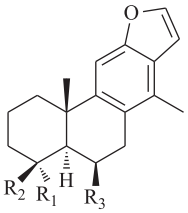

caesalpinins H 20 R_1=OH;R_2=OAc
caesalpinins O 21 R_1=OAc;R_2=OH

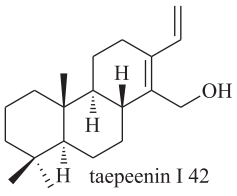

Pulcherrins D 22 R_1=R_2=H
Pulcherrins E 23 R_1=H;R_2=OH
Pulcherrins F 24 R_1=H;R_2=OAc
Pulcherrins G 25 R_1=H;R_2=OH
Pulcherrins H 26 R_1=OCOPh;R_2=H
Pulcherrins I 27 R_1=H;R_2=OCOPh
Pulcherrins J 28 R_1=H;R_2=OCOCH=CHPh

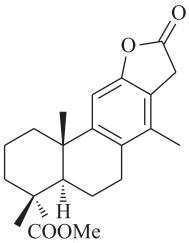

Pulcherrins K 29 R_1=CHO;R_2=OCOPh;R_3=OH
Pulcherrins L 30 R_1=CH_2OCOPh;R_2=OH;R_3=H
Pulcherrins M 31 R_1=COOH;R_2=OCOPh;R_3=H
Pulcherrins N 32 R_1=R_3=OCOPh;R_2=COOH;R_4=H

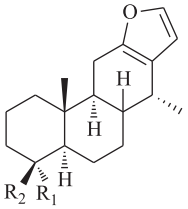

Pulcherrins O 33 R_1=Me;R_2=OAc;R_3=OH
Pulcherrins P 34 R_1=CH_2OAc;R_2=OH;R_3=OAc

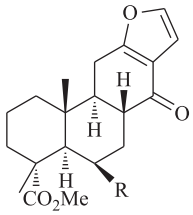

Pulcherrins Q 35

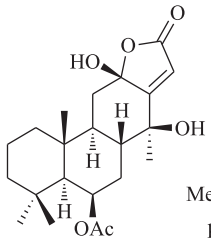

taepeenin A 37 R_1=COOMe;R_2=Me;R_3=H
taepeenin B 38 R_1=COOH;R_2=Me;R_3=H
taepeenin C 39 R_1=COOMe;R_2=Me;R_3=OH
taepeenin D 40 R_1=COOMe;R_2=Me;R_3=OCOMe
taepeenin E 41 R_1=COOMe;R_2=CHO;R_3=H


taepeenin I 42

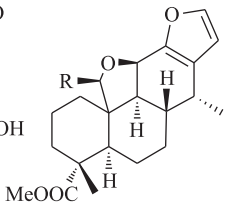

taepeenin F 43


taepeenin J 44 R_1=COOMe;R_2=CHO
taepeenin K 45 R_1=COOMe;R_2=CH_2OH

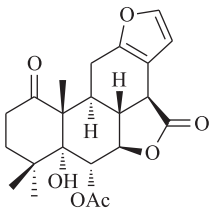

taepeenin G 46 R=H
taepeenin H 47 R=OH



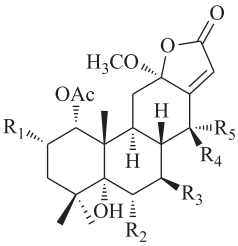
caesalpinolide B 48



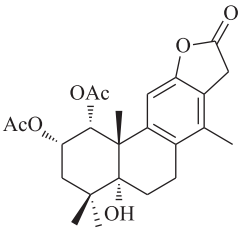
phanginin G 49 R=OH
phanginin H 50 R=H



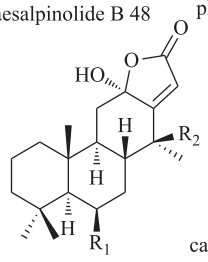
caesalpinins I 51



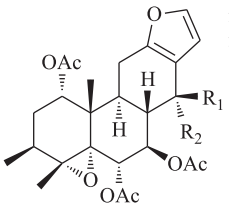
neocaesalpin AA 52 R_1=OAc;R_2=R_3=H;R_4=OH;R_5=Me
neocaesalpin AB 53 R_1=R_2=R_4=H;R_3=OH;R_5=CH_3
neocaesalpin AC 54 R_1=R_2=R_5=H;R_3=OH;R_4=COOMe



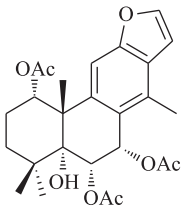
neocaesalpinA D 55



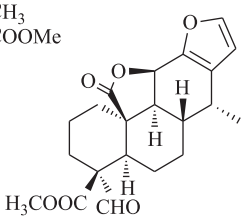
caesalpinolide-C 56 R_1=OH;R_2=H
caesalpinolide-E 57 R_1=OAc;R_2=H
caesalpinolide-D 58 R_1=H;R_2=OH
caesalpinolide A 59 R_1=OAc;R_2=OH



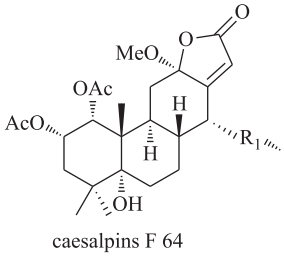
caesalpinins MM 60 R_1=Me;R_2=OH
caesalpinins MN 61 R_1=OH;R_2=Me



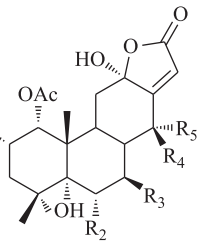
caesalpines D 62



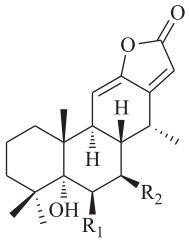
phanginin M 63

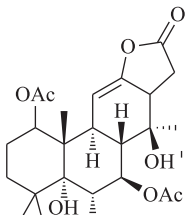


caesalpins F 64

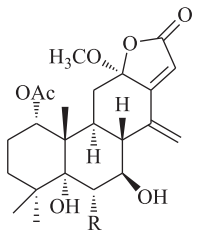


12α-methoxyl, 5α, 14β-dihydroxy-1α, 6α, 7β-triacetoxycass-13(15)-en-16, 12-olide 65 R_1=H;R_2=R_3=OAc;R_4=OH;R_5=Me
neocaesalpinJ66 R_1=OAc;R_2=R_3=R_5=H;R_4=Me
neocaesalpinK67 R_1=OAc;R_2=R_3=H;R_4=Me;R_5=OMe
neocaesalpinL68 R_1=H;R_2=R_3=OAc;R_4=OH;R_5=Me
neocaesalpinM69 R_1=H;R_2=R_3=OAc;R_4=OMe;R_5=Me
neocaesalpinN70 R_1=R_2=R_5=H;R_3=OH;R_4=COOMe

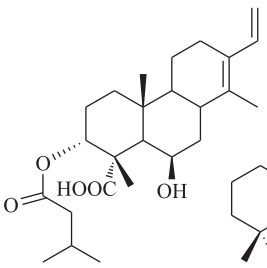




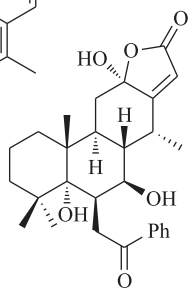
neocaesalpin P 71 R_1=OCOCH=CHPh;R_2=OH
neocaesalpin Q 72 R_1=OCOPh;R_2=H
neocaesalpin R 73 R_1=OCOPh;R_2=OH
neocaesalpin O 74



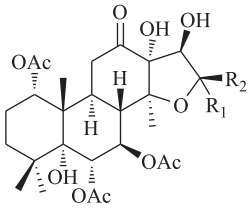
caesalpins G 75 R=H
caesalpins H 76 R=OAc



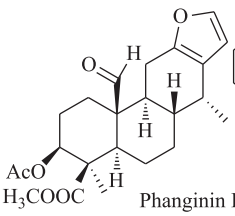
caesaldeca 77



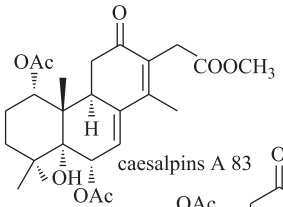
12-demethylneocaesalpin F 78



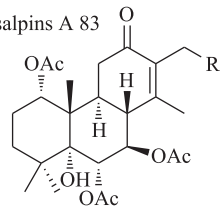
neocaesalpin AE 79 R_1=OCH_3;R_2=H
caesalminaxins E1 80 R_1=OH;R_2=H
caesalminaxins E2 81 R_1=H;R_2=OH



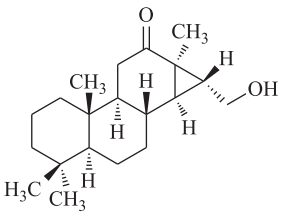
Phanginin L 82



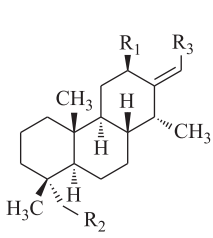
caesalpins A 83



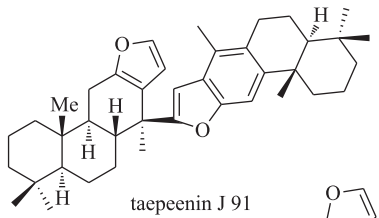
caesalpins C 84 R=$CH(OCH_3)_2$
caesalpins B 85 R=COOMe



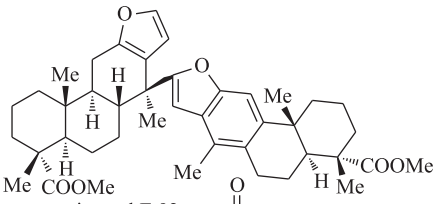
pulcherrins R 86



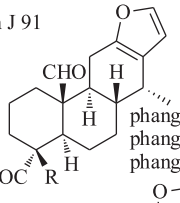
taepeenin K 87 R_1=R_2=H;R_3=CHO
taepeenin L 88 R_1=R_2=H;R_3=CH_2OH
mimosol B 89 R_1=OH;R_2=H;R_3=CH_2OH
mimosol C 90 R_1=H;R_2=OH;R_3=CH_2OH



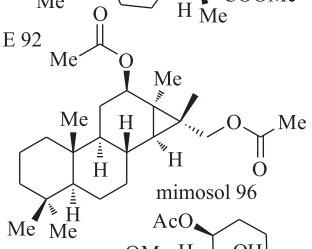
taepeenin J 91



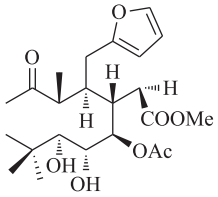
mimosol E 92



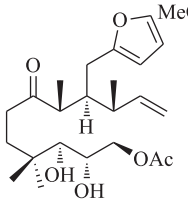
phanginin I 93 R=Me
phanginin J 94 R=CHO
phangininK 95 R=COOMe



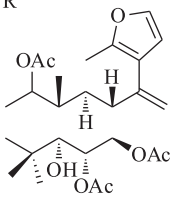
mimosol 96



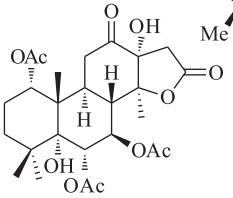
bonducellpins E 97



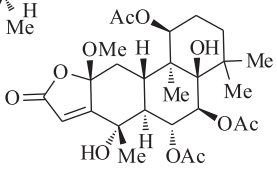
bonducellpins F 98



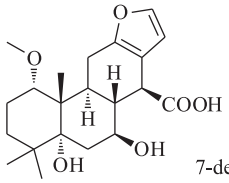
bonducellpins G 99



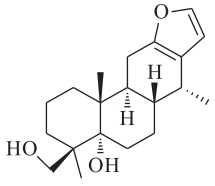
magnicaesalpin 100



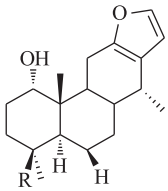
NeocaesalpinL 1 101



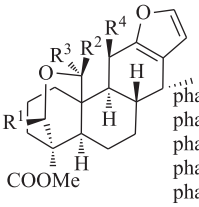
17-*O*-demehylbonducellpin C 102



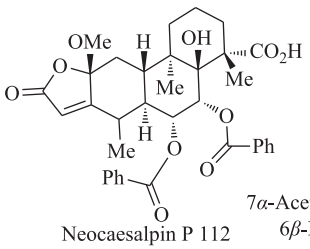
7-dehydroxycaesaldekarin I 103



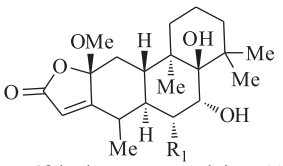
1b,5a-dihydroxyvoucapane 104 R=Me
1b,6b-dihydroxyvoucapane;19*β*-methylester(2)22-2 105 R=COOMe



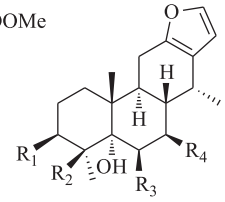
phangininA 106 R_1=R_3=R_4=H;R_2=OH
phanginin-B 107 R_1=OH;R_2=R_3=R_4=H
phanginin-C 108 R_1=R_2=R_4=H;R_3=OMe
phanginin D 109 R_1=OMe;R_2=R_3=R_4=H
phanginin E 110 R_1==O;R_2=R_3=R_4=H
phanginin F 111 R_1=R_2=H;R_3=R_4=OH



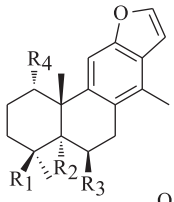
Neocaesalpin P 112



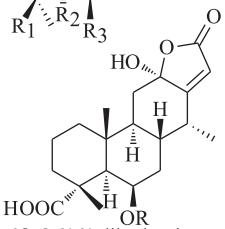
7*α*-Acetoxy-6*β*-hydroxyneocaesalpin E 113 R_1=OAc
6*β*-Hydroxyneocaesalpin E 114 R_2=H

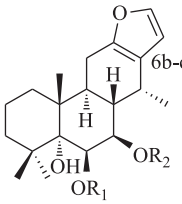


pulcherrin A 115 R_1=H;R_2=Me;R_3=OH;R_4=OCOCH=CHPh
pulcherrin B 116 R_1=OCOPh;R_2=Me;R_3=H;R_4=OH



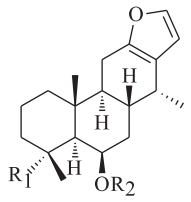
benthaminin 1 117 R_1=CO_2Me;R_2=H;R_3=H
caesalpinins MP 118 R_1=Me;R_2=OH;R_3=H
6*β*-acetoxy-17-methylvoucapane-8(14),-9(11)-diene 119 R_1=Me;R_2=H;R_3=OAc





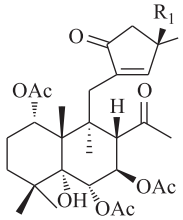
6b-cinnamoyloxy-7b-acetoxyvouacapen-5a-ol 122 R_1=
6b,7b-dibenzoyloxyvouacapen-5a-ol 123 R_1=
R_2=COMe
R_2=

6*β*-*O*-2',3'-dihydrocinnamoyl-12-hydroxy-(13)15-en-16,12-olide-18-cassaneoicacid 120:R=
6*β*-*O*-cinnamoyl-12-hydroxy-(13)15-en-16,12-olide-18-cassaneoicacid 121 R=

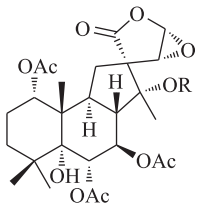


6β-O-6',7'dihydroxycinnamoyl-18-vouacapaneoicacid 124 R_1=COOH
6β-O-cinnamoyl-18-vouacapaneol 125 R_1=CH_2OH
6β-hydroxi-18-vouacapaneoicacid 126 R_1=COOH

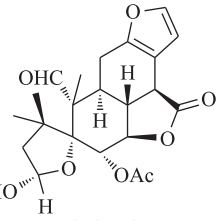
R_2=
R_2=
R_2=H



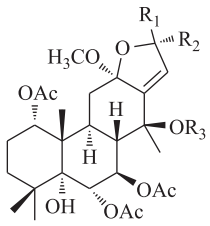
caesalminaxins A 1 127 R_1=OH;R_2=H
caesalminaxins A 2 128 R_1=H;R_2=OH



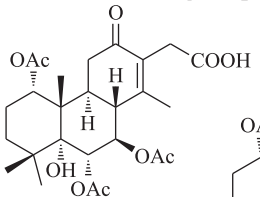
caesalminaxins B 3 129 R=H
caesalminaxinsc 4 130 R=CH_2CH_3



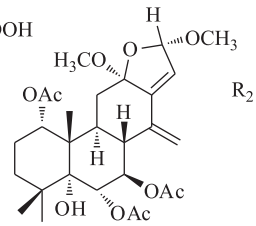
caesalminaxins E 131



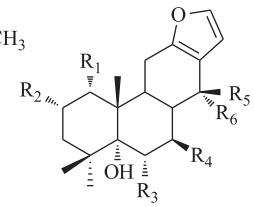
caesalminaxins F 8 132 R_1=OCH_3;R_2=H;R_3=H
caesalminaxins IG 133 R_1=OCH_3;R_2=H;R_3=CH_3
caesalminaxins H 10 134 R_1=H;R_2=OCH_3;R_3=H
caesalminaxins I 11 135 R_1=H;R_2=OCH_3;R_3=CH_3



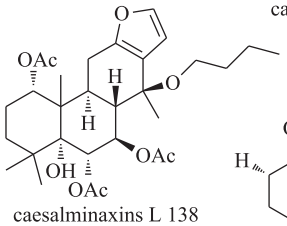
caesalminaxins K 136



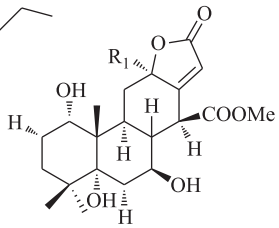
caesalminaxins J 137



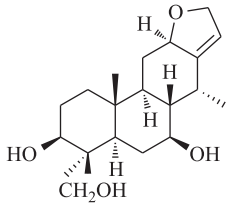
caesalpinin M 1 139 R_1=R_2=R_4=OH;R_3=OAc;R_5=$COOCH_3$;R_6=H
caesalpinin M 2 140 R_1=R_2=R_3=OH;R_4=OAc;R_5=$COOCH_3$;R_6=H
caesalmin E 1 141 R_1=OAc;R_2=R_3=H;R_4=R_5=OH;R_6=CH_3
caesalmin E 2 142 R_1=R_4=OAc;R_2=H;R_3=R_5=OH;R_6=CH_3
caesalmin E 3 143 R_1=R_3=OAc;R_2=H;R_4=R_5=OH;R_6=CH_3



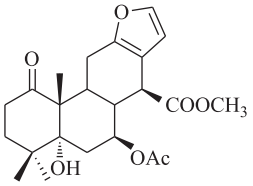
caesalminaxins L 138



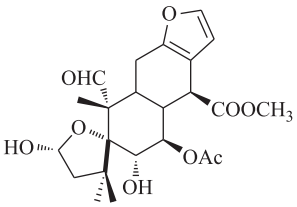
1-deacetyl-12-ethoxyneocaesalpin N 144 R_1=EtO
1-deacetylneocaesalpin N 145 R_1=OH



14-dehydroxy-12,16-dihydrocaesaldekarin L 146

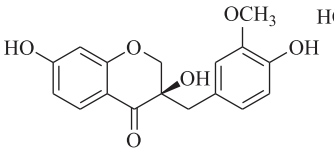


caesalpinin F 1 147

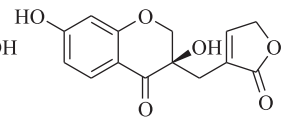


spirocaesalmin B 148

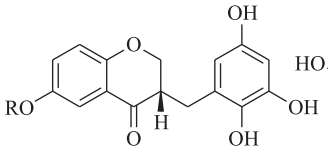
图 1　云实属植物中的二萜类化合物



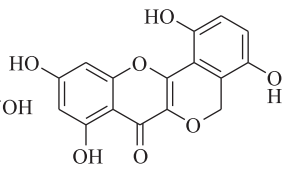
caesalpiniaphenols A 149



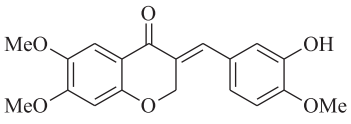
caesalpiniaphenols B 150



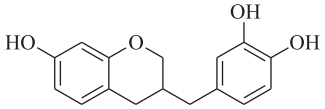
caesalpinianone 151 R=H
6-*O*-methylcaesalpinianone 152 R=CH_3



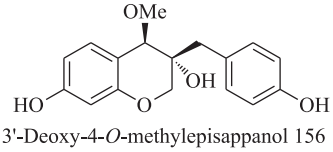
Minaxin 153



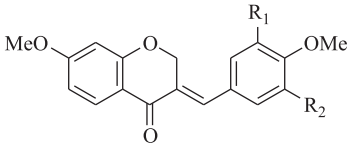
(3*E*)-2,3-dihydro-6,7-dimethoxy-3[(3-hydroxy-4-methoxyphenyl)methylene]-4H-1-benzopyran-4-one 154



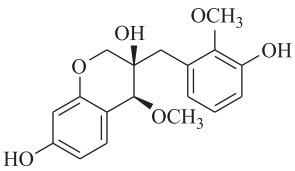
7,3',4'-trihydroxy-3-benzyl-2H-chromene 155



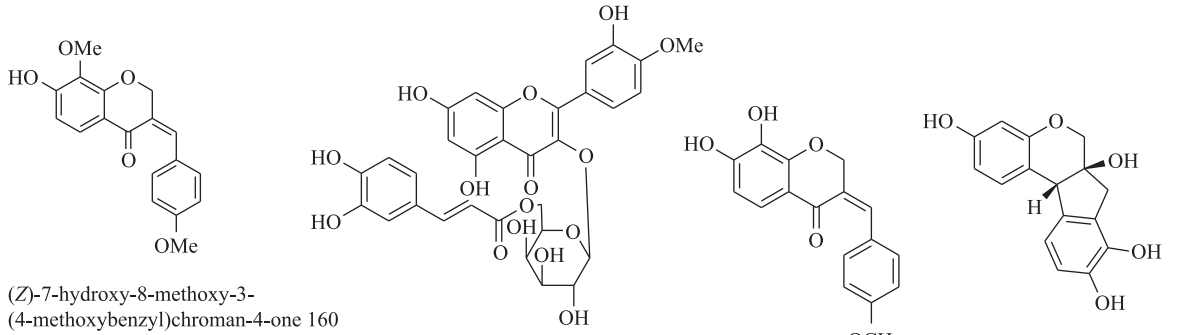
3'-Deoxy-4-*O*-methylepisappanol 156



(*E*)-7-methoxy-3-(4'-methoxybenzylidene)chroman-4-one 157 R_1=R_2=OMe
(*E*)-7-hydroxy-3-(3',4',5'-trimethoxybenzylidene)chroman-4-one 158 R_1=R_2=H



caesalpiniaphenol F 159



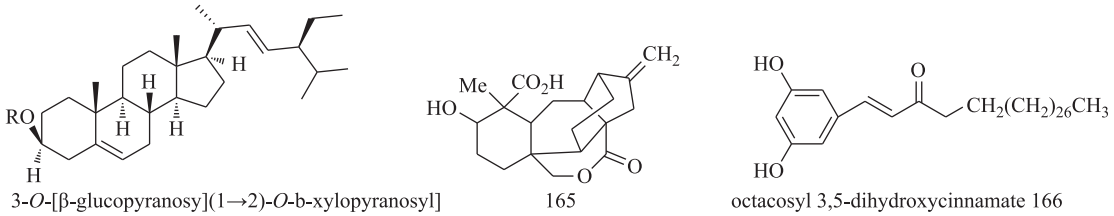
(*Z*)-7-hydroxy-8-methoxy-3-(4-methoxybenzyl)chroman-4-one 160

tamarixetin3-*O*-(6''-*O*-*E*-caffeoyl)-b-D-galactopyranoside 161

isointricatinol(I) 162

caesalpiniaphenol E 163

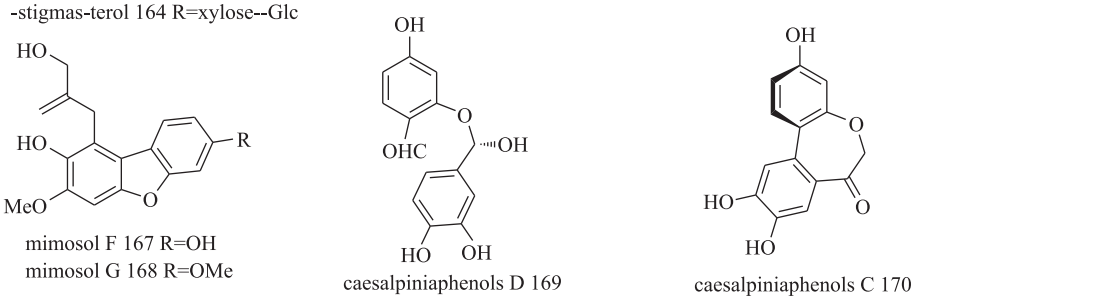
图 2　云实属植物中的黄酮类化合物



3-*O*-[β-glucopyranosy](1→2)-*O*-b-xylopyranosyl]-stigmas-terol 164 R=xylose--Glc

165

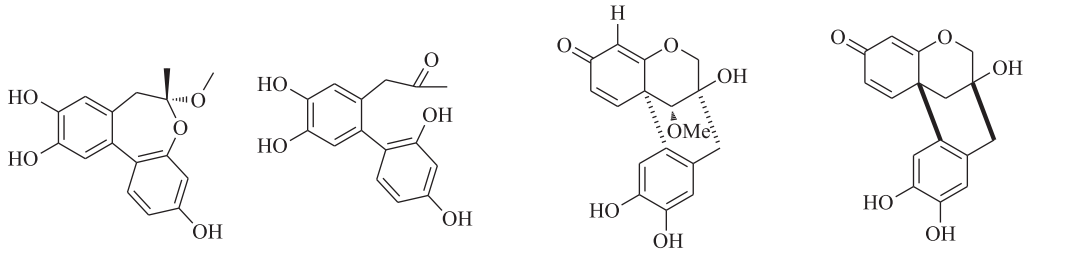
octacosyl 3,5-dihydroxycinnamate 166



mimosol F 167 R=OH
mimosol G 168 R=OMe

caesalpiniaphenols D 169

caesalpiniaphenols C 170

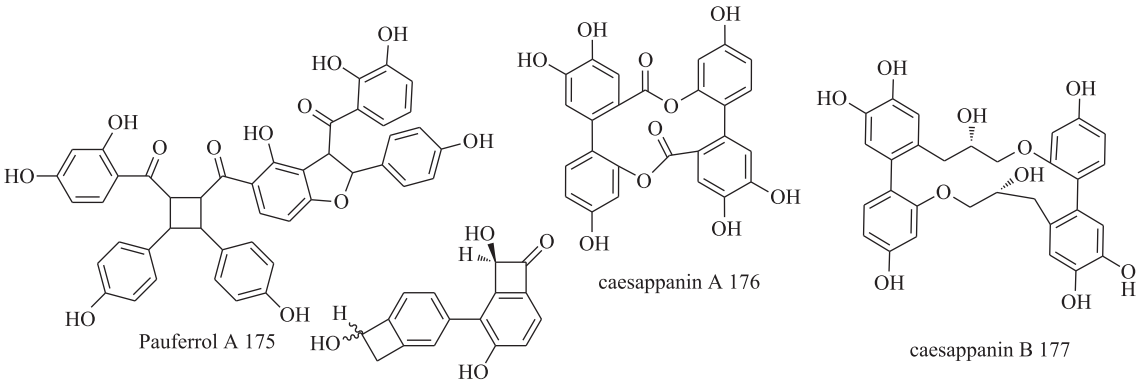


Caesappin A 171

Caesappin B 172

epicaesalpin J 173

7,10,11-trihydroxydracaenone 174



Pauferrol A 175

caesappanin A 176

caesappanin B 177

6'-hydroxy-3,4-(1''-hydroxy-epoxy-propane)-2',3'-(1''b-hydroxy-2'''-carbonyl-cyclobutane)-1,1'-diphenyl 178

图 3　云实属植物中的其他化合物

巨噬细胞中脂多糖(LPS)诱导的一氧化氮(NO)产量进行抗炎活性评价，表现出较强的抑制效果：IC_{50}值分别为 12.5、8.1 μmol·L^{-1}。Yodsaoue Orapun 等[27]从 *C. pulcherrima* 分离得到 pulcherrins K、L、M 等也有潜在的抗炎活性。Hu Jun[46]研究了 *C. sappan* L. 干燥心材 95% 乙醇提取液，从中分离得到 protosappanin A、B 和 brazilein，在体外均有较好的抗氧化活性。

2.2 抗肿瘤活性

Caesalpinolide A-E 均从热带云实豆中得到。Caesalpinolide A 和 B 是差向异构体，抑制 MCF-7 乳腺癌细胞系细胞增殖的半数抑制浓度(IC_{50})值分别为 12.8、6.1 μmol·L^{-1}，同时伴有抑制子宫内膜癌和宫颈癌细胞系细胞增殖的作用。此外，Caesalpinolide D 在对抗宫颈癌、前列腺癌和乳腺癌细胞系细胞增殖方面也表现出较好的活性[10,13]。

Ma Guoxu 等[8]从苦石莲种子中分离得到 Caesalpin A-H，Caesalpin A 表现出较强的抗恶性细胞增生的活性：对 HepG-2 细胞的 IC_{50}值为 4.7 μmol·L^{-1}，对 MCF-7 细胞的 IC_{50}值为 2.1 μmol·L^{-1}。

2.3 抗疟疾活性

Bonducellpins E-G 是从热带云实豆(*C. bonduc*)种子乙酸乙酯溶性部位分离得到的。对耐多药菌株 K_1 恶性疟原虫生长表现出较好的抑制活性，IC_{50}值分别为 1.6、5.8、3.8 μmol·L^{-1}[22]。

3　结论

云实属植物具有较好的生物活性，近些年主要的研究方向集中在二萜类化合物上，并且报道了很多具有较强生物活性的化学成分。需要继续深入进行云实属植物化学成分的研究，探讨其抗肿瘤、抗氧化、抗炎等方面的生物活性，提高云实属植物资源的综合利用价值。

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