雪莲花主要活性成分及其在化妆品中的功效研究进展

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摘　　要：雪莲花具有很强的抗炎、抗氧化、防辐射、美白生物活性，在化妆品中具有独特的价值，这与其蕴含的倍半萜类、黄酮类、香豆素类、酚酸、木脂素、苯丙素、多糖等物质密切相关。文章通过收集和查阅国内外大量文献资料，总结和阐述雪莲花在化妆品中相关生物活性及其作用机制的研究现状，以期为雪莲花在化妆品领域的开发与利用提供参考价值。

关　键　词：雪莲花；生物活性；化学成分；化妆品

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雪莲花（*Saussurea involucrate* (Kar. et Kir) Sch.-Bip.），又称天山雪莲，新疆雪莲，大苞雪莲，雪荷花。菊科（Compositae），风毛菊属（*Saussurea*），多年生草本，是维吾尔医药中的常用民族药，维吾尔名塔裕依力斯。主要分布于新疆境内的天山山脉、阿勒泰山脉和昆仑山脉。雪莲花能够在海拔3000米左右、常年积雪不化、气候严寒的雪峰生长，有着极强的生命力。特殊的生长环境使其天然而稀有，并造就其独特神奇的药理作用[1]。雪莲花仅由种子进行繁殖，自然繁殖率极低。在自然条件下，雪莲种子萌发及幼苗成活率低于5%，从种子萌发到开花结实一般要5-6年[2]。雪莲花所含成分较多、比较复杂。按化学结构来分，主要含有倍半萜类、黄酮类、香豆素类、木脂素类、苯丙酸类、不饱和脂肪酸以及多糖类等多种化学成分[3-5]。民间以全草入药，具有抗炎、镇痛、活血通经、散寒除湿，强筋助阳等功效，用于治疗风湿性关节炎，肺寒咳嗽，小腹冷痛，闭经，胎衣不下，阳萎等疾患[6]。

然而，尽管雪莲花作为《化妆品已使用目录（2015版）》原料，但是关于雪莲花在化妆品中的应用不够明朗。因此，文章通过调研雪莲花在化妆品领域相关的功效及其活性物质为主要目的，通过收集和查阅国内外文献资料，对现阶段雪莲花已被报道的生物活性及其发挥功效的化学成分进行了归纳与总结，发现雪莲花具有抗氧化、抗炎、防辐射、美白生物活性，在化妆品中具有广阔的应用前景，希望为雪莲花在化妆品中更科学有效地应用提供参考价值。

1. 雪莲花生物活性研究

1.1 抗炎活性

皮肤炎症反应受信号通路的严格调控，其中核因子-κB（Nuclear factor kappa-light-chain-enhancer of activated B cells, NF-κB）作为一种普遍存在的转录因子，和丝裂原活化蛋白激酶（Mitogen-activated protein kinase, MEK）以及磷脂酰肌醇3-激酶（Phosphoinositide 3-kinase, PI3K）通路，作为主要的信号通路，参与皮肤炎症反应[7]。活化的NF-κB和MEK能够上调环氧合酶-2（Cyclooxygenase-2, COX-2）、前列腺素E2（Prostaglandin E2, PGE-2）和诱导型一氧化氮合酶（nducible nitric oxide synthase, iNOS）的表达[8]。因此，抑制组织和/或器官中与炎症和疾病的慢性炎症调节机制，以确保其安全终止并恢复免疫稳态是发挥抗炎活性的重要手段[9]。

TCM（Traditional Chinese medicine）和/或TUM（Traditional Uyghur medicine）表明，雪莲花（*S. involucrat*）提取物在炎症和疼痛相关疾病中用作治疗剂被使用[10]。近年来对雪莲花提取物在抗炎，镇痛等方面也有了很多新的发现。研究表明，口服雪莲花提取物治疗II型胶原（collagen II, CII）诱导的关节炎大鼠模型发现，炎症细胞浸润、滑膜增生、肿胀指数和延迟关节破坏均得到缓解[11]。此外，在比较雪莲花的醇提取物和水提取物对类风湿关节炎的治疗作用研究中发现，乙醇提取物对类风湿关节炎大鼠模型的治疗作用强于水提取物，乙醇提取物显著改善了类风湿关节炎的严重程度，其作用机理为，明显减少了大鼠血清中过度产生的细胞因子，如TNF-α、IL-1β、IL-6以及血清类风湿因子、软骨低聚基质蛋白（cartilage oligomeric matrix protein, COMP）、c反应蛋白和抗-CII IgG抗体水平均显著降低[12]。另有研究表明，在培养的巨噬细胞上应用雪莲花提取物可以显著降低PGE_2和NO水平[13]。在LPS诱导巨噬细胞评价雪莲花提取物抗炎活性中发现，雪莲提取物通过NF-κB的转

位和 Erk1/2，JNK 和 Akt 的磷酸化，从而激活 NF－κ B/PI3K/MAPK 信号通路，减少 iNOS 和 COX－2 的表达 [14]。上述研究表明雪莲花提取物可通过调节炎症相关的介质及信号通路的表达发挥强大的抗炎活性，有望作为皮肤炎症抑制剂应用到化妆品领域中。

1.2 抗氧化活性

在生命过程中生物体不断产生氧自由基，如超氧阴离子自由基（$\cdot O_2^-$）、羟自由基（·OH）及有机自由基（R·, RO·, ROO·），还有一些含氧产物如单线态氧（$^1O_2$）、过氧化氢（H_2O_2）等。它们虽不属于自由基，但含有活性氧，化学性质较基态氧活泼，可在自由基反应中产生，同时还可直接或间接触发自由基反应，所以统称为活性氧（ROS）。它们有很强的反应性，当在机体中过剩产生时会损伤细胞膜，使 DNA 断裂、蛋白质变性、酶失活，最后导致细胞解体和死亡。在正常境况下，机体自身存在抗氧化系统，包括 GSH－Px、SOD 等抗氧化酶，维持机体的氧化平衡，对保护细胞结构和功能完整、延缓细胞衰老起着重要作用 [15]。

研究结果表明，雪莲花不同部位提取物对 Fe^{3+} 还原能力不同，对 Fe^{3+} 还原能力大小次序是：叶片 > 花苞片 > 花 > 根 > 茎。并且相关性分析表明雪莲花不同部位提取物对 Fe^{3+} 还原能力与其总酚和总黄酮含量呈正相关。天山雪莲叶片提取物和花苞片提取物对 DPPH 自由基的清除能力最强；花和茎提取物对 DPPH 自由基的清除能力最弱。花苞片提取物对 DPPH 自由基的清除率是 84.24%[16]。另外，在对雪莲花多糖（SIP）清除自由基和抗疲劳研究中发现，SIP 兼有清除 $\cdot O_2^-$、抗氧化、降低耗氧量和抗疲劳等作用也能解除疲劳等活性 [17]。此外，从雪莲花中分离得到的雪莲花多糖（Polysaccharides from cultivated *Saussurea involucrate*, CSIP）1－2 和 CSIP2－3 被证明可以有效地清除超氧自由基、DDPH 自由基和羟自由基，从而发挥抗氧化活性 [18]。

1.3 抗辐射活性

现代研究表明，雪莲花细胞提取物具有抗辐射作用。在连续 14d 给予小鼠雪莲花细胞提取物，然后进行一次性全身照射 $^{60}Co\ \gamma$ 2.5 Gy 处理，照射后各组小鼠继续每日灌胃给药 14d。检测结果表明，小鼠被 $^{60}Co\ \gamma$ 射线照射后的外周血白细胞数、淋巴细胞数、红细胞数、血红蛋白及血小板含量均显著下降；照射后小鼠继续灌服雪莲细胞提取物 14d 显著促进了这些指标的回升 [19]。另一研究发现，在连续 30d 灌胃给予小鼠雪莲花细胞乙醇提取物，在第 20 天行 $^{60}Co\ \gamma$ 照射，剂量 1.0Gy，每天 1 次共 10 次。结果发现，与空白给药组相比，雪莲花细胞乙醇提取物能使受照射小鼠的外周白细胞数、SOD 活性和平均存活时间显著增加，骨髓嗜多染红细胞微核率显著降低 [20]。此外，还有研究发现连续灌胃 50％雪莲水煎剂 20d，核辐射损伤小鼠的 T、B 淋巴细胞、巨噬细胞的功能和免疫细胞产生细胞因子的能力恢复明显。脾抗体形成数与照射未服药组相比从 44 增加到 108，与对照组比较差异具有显著性。同时雪莲花水煎液对于辐射导致的免疫力低下具有明显的免疫增强作用，能增强小鼠脾细胞的刀豆蛋白 A（Concanavalin A, ConA）增殖反应与混合淋巴细胞培养反应，与正常组比较有明显差异 [21,22]。

另外，用 Giemsa 染色法检查辐射所致的染色体特征性非稳定性畸变的研究中发现，雪莲花水提物对各种类型的染色体畸变，包括“双＋环”畸变、无着丝粒畸变都有显著的抑制作用；并发现雪莲花水提取物在清除 · OH 的能力的同时，既可以减轻辐射造成的急性损伤，又能显著减少染色体畸变；并且与雪莲花水提取物中含有的黄酮类和多糖类物质有关 [23]。

1.4 美白活性

黑色素是一种由表皮黑色素细胞产生的色素，负责皮肤颜色和保护皮肤免受紫外线照射 [24]。然而，黑色素的过量产生导致了不同的皮肤疾病，如皮肤老年斑、黄褐斑、雀斑、黄褐斑和黑色素瘤 [25]。研究表明，这些生理障碍主要归因于活性氧（ROS）的过度积累或氧化应激最终导致色素沉着 [26]。酪氨酸酶是一种双核含铜单加氧酶，是参与皮肤表皮黑色素生物合成的关键限速酶。黑素形成是由酪氨酸酶催化 1－酪氨酸羟基化成 1－3,4 二羟基苯丙氨酸（DOPA）而引发的。酪氨酸酶还参与了多巴到多巴醌的后续酶转化 [27]。因此，酪氨酸酶抑制剂是开发抗黑素生成原料的主要目标 [54]。ROS 可诱导氧化应激，是参与皮肤衰老过程的重要分子。据报道，ROS 可以增加角质形成细胞中 α－黑色素细胞刺激激素（MSH）的分泌，是引起色素沉着的关键分子 [28]。α－MSH 结合黑素细胞上的黑色素皮质素 1 受体，通过环磷酸腺苷（cAMP）依赖通路刺激小眼相关转录因子（MITF）的表达，导致黑素形成 [29]。因此，抗氧化剂如活性氧清除剂可能抑制表皮黑色素生成。

研究表明，中国传统草药雪莲花具有美白功效。在浓度为 100mg/kg 时，其乙醇提取物对黑色素细胞有明显的抑

制作用，但对正常 Mel−ab细胞的毒性很小[30]。另一研究发现，雪莲花培养物具有超强的抗氧化和抗黑色素能力，雪莲花培养物在浓度低至0.02mg/mL时，对黑色素合成的抑制率即可达到22.9%，这与葡萄籽提取物在相近浓度下的抑制黑色素合成能力相当[31]。

在评价雪莲提取物在黑色素瘤细胞中的潜在治疗功能研究中，雪莲花提取物（SIH）降低了黑色素含量水平，表明SIH对黑色素生成有抑制作用。另一方面，SIH处理可以减弱UV预处理的B16F10细胞中ROS的形成。进一步采用荧光素酶法测定SIH处理后抗氧化反应原件（Antioxidant response element, ARE）的转录功能，发现SIH以浓度依赖的方式增加ARE反应。此外，SIH可刺激核因子−E2相关因子2（Nuclear factor erythroid 2−related factor 2, Nrf2）的激活，表明SIH在暴露于UV的培养B16F10细胞中具有潜在的抗氧化作用。因此，SIH可能通过激活PI3K/Akt通路减少ROS形成，从而发挥其抑制黑素形成的作用[32]。

另一方面，研究了雪莲花总黄酮（SIFs）对抗氧化活性和抗黑色素沉积的影响，以及黑色素合成的相关基因。结果显示随着雪莲花类黄酮提取物的添加量的增加，DPPH、超氧阴离子、羟基自由基和$ABTS^+$的还原活性和清除率均有所提高。SIFs提取物通过抑制人黑色素瘤A375细胞酪氨酸酶活性诱导黑色素合成减少以及抑制黑色素合成相关酪氨酸酶基因的表达[33]。

此外，研究雪莲花多糖（SIP）在forskolin诱导的B16F10黑素瘤细胞中的体外抗氧化活性和抗黑素生成作用实验中发现，SIP具有较强的抗氧化活性，并能浓度依赖性地减少forskolin诱导的B16F10细胞黑素生成和抑制酪氨酸酶活性。在此基础上，通过检测酪氨酸酶（TYR）、酪氨酸酶相关蛋白−1（TRP−1）、酪氨酸酶相关蛋白−2（TRP−2）、MITF、环磷腺苷反应元件结合蛋白（CREB）、丝裂原活化蛋白激酶（MAPK）信号蛋白成员以及β−连环蛋白（β−catenin）降解，研究forskolin抑制B16F10细胞黑素生成的机制发现，SIP的抗黑素生成作用可能与调节c−Jun氨基末端激酶（JNK）磷酸化和β−catenin降解途径有关。因此，雪莲多糖具有较强的抗黑素作用[34]。

1.5 小结

通过对雪莲花在化妆品相关生物活性文献调研发现，雪莲花不同提取溶剂对产品功效影响较大，雪莲花乙醇提取物因其富含黄酮类化合物，具有强大的抗炎、抗氧化、防辐射、美白活性，建议作为雪莲花提取物重点关注的功效成分。另一方面，雪莲花不同使用部位发挥的生物活性也不近相同，叶提取物的抗氧化活性明显优于茎，因此在雪莲花提取物的制备过程中需要考虑不同提取溶剂、不同使用部位对功效的影响。

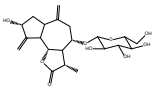
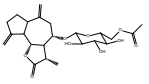
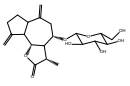
此外，进一步对雪莲花进行植物化学文献调研发现，雪莲花中的化学成分较为复杂，含有的化学成分除黄酮、多糖类物质外，还含有丰富的倍半萜内酯类化合物以及酚酸、木脂素、生物碱、香豆素类化合物[5]。但缺少对这些成分在化妆品相关生物活性的研究，下面将通过文献调研的方式对雪莲花中被报道的化学成分进行化妆品相关生物活性研究，并尝试汇总雪莲花不同化学成分在发挥化妆品相关活性中的物质基础，为雪莲花提取物的制备以及在化妆品中的应用提供潜在价值。

2. 雪莲花提取物化学成分及其在化妆品中的生物活性研究

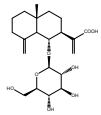
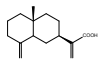
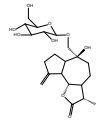
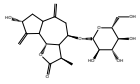
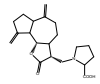
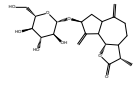
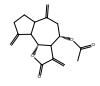
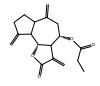
2.1 倍半萜类化合物

倍半萜类化合物为雪莲的特征性成分，也是其主要成分，研究发现，雪莲中含有一系列愈创木酚内酯型(guaianolides)倍半萜类化合物[34−38]。

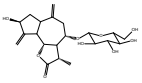
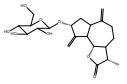
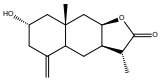
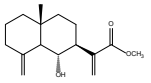
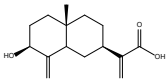
表1 雪莲花中倍半萜内酯类化合物结构与生物活性

序号	结构式	名称	生物活性
1		3α,8α−Dihydroxy,11βH−11,13−dihydrodehydrocostus lactone	
2		8α−Hydroxy,11βH−11,13−dihydrodehydrocostus lactone	抗炎[36]
3		8β−Hydroxy,11βH−11,13−dihydrodehydrocostus lactone	
4		3α−Hydroxy11βH−11,13−dihydrodehydrocostus lactone−8−*O*−β−D−glucoside (3α−Hydroxy 11βH−11,13−dihydro 8α−*O*−β−D−glucozaluzanin)	抗炎[39]
5		11βH−11,13−Dihydrodehydrocostus lactone−8α−O−(6’−acetyl)−β−D−glucopryranoside	
6		11βH−11,13−Dihydrodehydrocostus lactone−8−*O*−β−D−glucopyranoside	抗炎[36]

续表 1 雪莲花中倍半萜内酯类化合物结构与生物活性

序号	结构式	名称	生物活性
7		6 α −Hydroxycostic acid 6− β −D−glucopyranoside	
8		β −Costic acid	抗炎 [40]
9		10*β*,14−Dihydroxy−11*β*H−guaia−4(15)−ene−12,6 α −olide14−*O*− β −D−glucoside	
10		Japonicolactone	
11		Dihydrodehydrocostus lactone	抗炎 [39]
12		11,13−Dihydrodesacylcynaropicrin	
13		11 β ,13−Dihydrodesacylcynaropicrin 8− β −D−glucoside	
14		11 α ,13−Dihydrodenhydrocostus lactone (mokko lactone)	抗炎 [41]
15		Dihydrozaluzanin C	
16		Involucratine	
17		Xuelian lactone	
18		11*β*H,13−Dihydroglucozaluzanin C	
19		Dehydrocostus lactone	抗炎 [42] 抗菌 [43]
20		8 α −Hydroxydehydrocostus lactone	抗菌 [44]
21		8 α −Acetoxydehydrocostus lactone	
22		8 α −Propionyloxy−dehydrocostus lactone	
23		Zaluzanin C	抗炎 [44,45]

续表 1 雪莲花中倍半萜内酯类化合物结构与生物活性

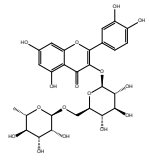
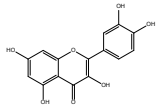
序号	结构式	名称	生物活性
24		11 β ,13−Dihydrocdeacyclcynaropic−rin (sausinlactones C)	
25		Sausinlactone A (1S,3S,5S,6S,7S,11S)−3−hydroxyl−11,13−dihydrodehydrocostuslactone)	
26		Sausinlactone B (1S,3S,5S,6S,7S,11R)−3−hydroxyl−11,13−dihydrodehydrocostuslactone)	
27		11 β ,13−Dihydrocdeacyclcynaropicrin 8− β −D−glucoside lactone	抗炎 [39]
28		11 α ,13 −Dihydroglucozaluzanin C	
29		11*β*H−2 α −Hydroxy−eudesman−4(15)−en−12,8 β −olide	
30		6 α −Hydroxycostic acid methyl ester	
31		3 β −Hydroxycostic acid	

愈创木酚内酯型倍半萜内酯类化合物广泛存在于菊科植物中，现代研究表明，其具有较为广泛的抗炎、抗菌等生物活性 [46]。有研究表明，愈创木酚内酯型倍半萜内酯类化合物可以抑制巨噬细胞 NF− κ B 与 MAPK 信号通路，从而降低 COX−2 和 iNOS 的表达，以及促炎症因子 TNF− α ，IL−6 的分泌，抑制炎症反应的发生 [47−49]。

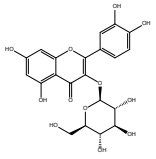
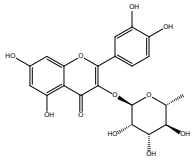
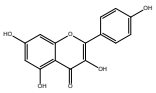
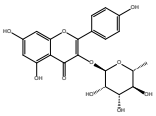
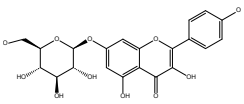
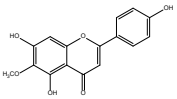
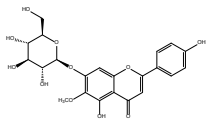
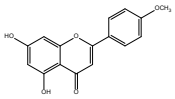
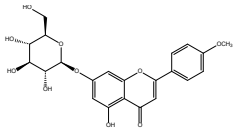
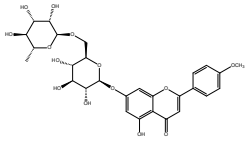
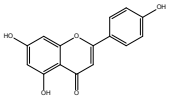
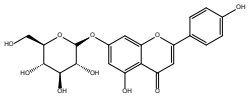
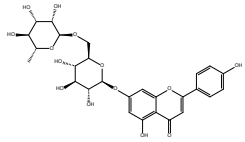
2.2 黄酮类化合物

黄酮类化合物及其糖苷类化合物是雪莲中主要的生物活性成分，并在雪莲植物中含量较高，涉及黄酮、黄酮醇、二氢黄酮等多种类型化合物，并且以芦丁含量较高 [34−37]。

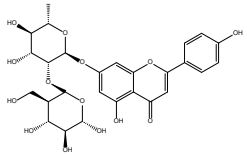
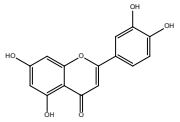
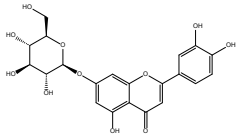
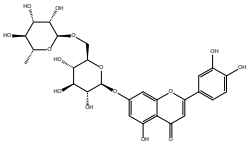
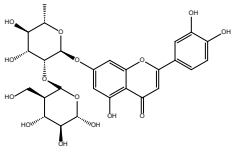
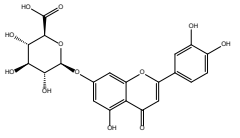
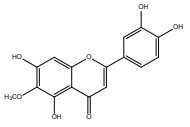
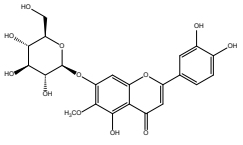
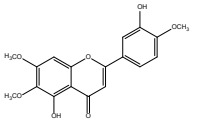
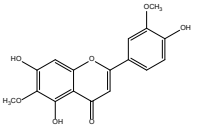
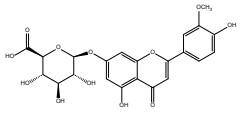
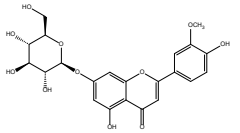
表 2 雪莲花中黄酮类化合物结构与生物活性

序号	结构式	名称	生物活性	文献
1		Rutin	抗氧化、抗炎美白、	[50] [51]
2		Quercetin	抗氧化、抗炎、美白、抗菌、抗衰老	[52,53] [54] [55] [56] [87]

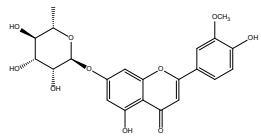
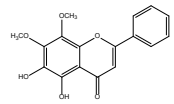
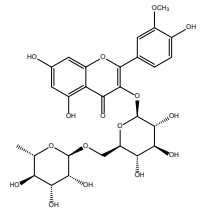
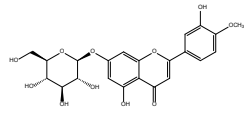
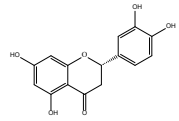
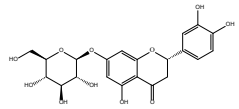
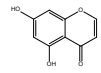
续表2 雪莲花中黄酮类化合物结构与生物活性

序号	结构式	名称	生物活性	文献
3		Isoquercitrin	抗氧化、抗炎、抗衰老	[58] [59] [60]
4		Quercitrin	抗氧化抗炎	[61,62] [63]
5		Kaempferol (pelargidenon)	抗氧化、抗炎、抗衰老	[64] [64] [65]
6		Afzelin (Kaempferol−3−*O*−rhamnoside)	抗氧化、抗菌、抗炎	[66] [66] [67]
7		Kaempferol−7−*O*− β −D−glucopyranoside (populnin)	抗氧化	[68]
8		Hispidulin (Dinatin)	抗氧化、抗炎	[69] [70]
9		Hispidulin−7−*O*−glucoside (homoplantaginin)	抗氧化、抗炎	[71] [72]
10		Acacetin	抗氧化、抗炎、抗光老化	[73] [73] [74]
11		Acacetin−7−*O*−glucoside (tilianin)	抗氧化、抗炎、美白	[75] [75] [76]
12		Acacetin−7−*O*− β −D−rutinoside (linarin)	抗氧化、抗炎	[77] [78]
13		Apigenin	抗氧化、抗炎、抗衰老	[64] [64] [79]
14		Apigenin−7−*O*− β −D−glucopyranoside	抗氧化、抗炎	[80] [181]
15		Apigenin−7−O− β −D−rutinoside	抗氧化、	[82]

续表2 雪莲花中黄酮类化合物结构与生物活性

序号	结构式	名称	生物活性	文献
16		Apigenin−7−*O*− α −L−rhamnoside−(1→2)− β −D−glucopyranoside		
17		Luteolin	抗氧化、抗炎、抗衰老	[64] [64] [83]
18		Luteolin−7−*O*− β −D−glucopyranoside	抗氧化、抗炎	[84] [84]
19		Luteolin−7−*O*− β −D−rutinoside (lonicerin)	抗氧化、抗炎	[85] [86]
20		Luteolin−7−*O*− α −L−rhamnoside−(1→2)− β −D−glucopyranoside		
21		Luteolin−7−*O*−glucuronide	抗氧化、抗炎	[87] [88]
22		Nepetin	抗氧化、抗炎、抗菌	[89] [90] [89]
23		Nepetin−7−*O*−gl−ucoside (nepetrin)		
24		Eupatorin	抗氧化、抗炎	[91] [92]
25		Jaceosidin	抗氧化、抗炎	[93] [93]
26		Chrysoeriol−7−*O*−glucuronide	抗氧化、	[94]
27		Chrysoeriol−7−*O*−glucoside	抗氧化、	[95]

续表2 雪莲花中黄酮类化合物结构与生物活性

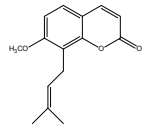
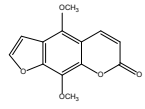
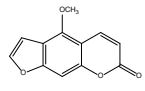
序号	结构式	名称	生物活性	文献
28		Chrysoeriol−7−O−rhamnoside		
29		5,6−Dihydroxy−7,8−dimethoxyflavone		
30		Isorhamnetin−3−*O*−rutinoside	抗氧化、抗炎	[96] [97]
31		Diosmetin−7−*O*−β−D−glucopyranoside	抗氧化、抗炎	[98] [99]
32		Eriodictyol	抗氧化、抗炎、美白	[100] [100] [101]
33		Eriodictyol−7−*O*−glucoside	抗氧化	[102]
34		5,7−Dihydroxy chromone		

雪莲花中含有的黄酮类化合物种类较多，含量也极为丰富。具有强大的抗氧化，抗炎作用。此外，黄酮类化合物由于存在共轭结构，对紫外线有吸收作用，从而抵挡紫外线造成的不良影响，是天然植物源防晒剂，因此具有防晒与光保护功效[133−135]。

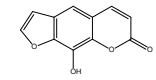
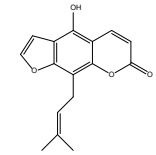
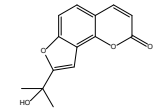
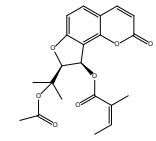
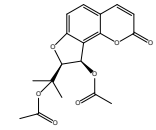
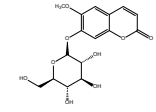
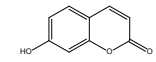
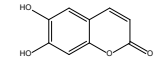
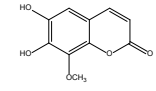
2.3 香豆素类化合物

研究发现，雪莲花中含有香豆素类化合物，且以呋喃香豆素种类较多[34−37]。

表3 雪莲花中香豆素类化合物结构与生物活性

序号	结构式	名称	生物活性	文献
1		Osthol	抗氧化、抗炎、美白	[106] [106] [107,108]
2		Isopimpinellin	促黑素合成	[108]
3		Bergapten	促黑素合成、抗炎、抗氧化	[108] [109] [109]

续表3 雪莲花中香豆素类化合物结构与生物活性

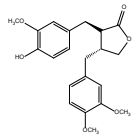
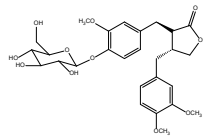
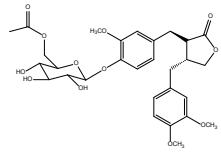
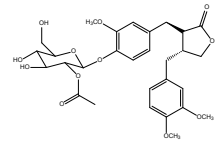
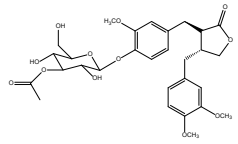
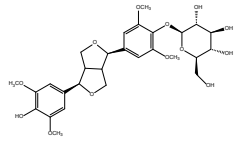
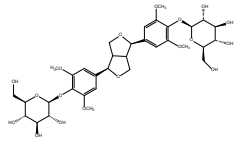
序号	结构式	名称	生物活性	文献
4		Xanthotoxol	抗炎、抗氧化	[110] [111]
5		Alloisoimperatorin	抗氧化	[112]
6		Oroselol	抗菌	[113]
7		Edultin	促黑素合成	[108]
8		Vaginidiol diacetate		
9		Scopolin	抗炎	[114]
10		Umbelliferone	促黑素生成、抗氧化、抗菌、抗炎	[115] [116] [116] [117]
11		Esculetin	美白、抗炎、抗氧化	[118] [119] [120]
12		Isofraxidin	抗氧化、抗炎、美白	[121] [122] [123]

由此可见，雪莲花中含有的香豆素类化合物具有广泛的生物活性，但在黑色素调节作用方向上，需要注意的是，不同化学结构的香豆素类物质既有可以抑制黑色素合成的成分，也有促进黑色素合成的成分，因此需要进一步明确对香豆素类化合物发挥黑色素调节作用构效关系的研究，明确不同香豆素类化合物的结构对黑色素调节的影响。此外，香豆素类物质还具有抗氧化、抗炎生物活性，推测与其含有的酚羟基的数量及取代基的位置有关。

2.4 木脂素类化合物

植物化学研究表明，雪莲花中含有的木脂素类化合物主要包括二苄基丁内酯类（dibenzyltyrolactones），如牛蒡子苷及其牛蒡子苷元等，此外还含有骈双四氢呋喃类（furofurans）木脂素化合物[34−37]。

表4 雪莲花中木脂素类化合物结构与生物活性

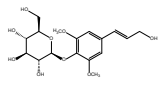
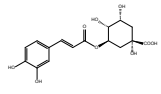
序号	结构式	名称	生物活性	文献
1		Arctigenin	美白、抗炎、抗氧化	[124] [125] [125]
2		Arctiin	美白、抗炎、抗衰老	[124] [126] [127]
3		Arctigenin−4−*O*−(6″−*O*−acetyl)−β −D−glucoside		
4		Arctigenin−4−*O*−(2″−*O*−acetyl−β −D−glucoside)		
5		Arctigenin−4−*O*−(3″−*O*−acetyl−β −D−glucoside)		
6		Acanthoside B (Eleutheroside E1)	抗氧化	[128]
7		Eleutheroside E	抗氧化、抗炎	[129] [129]

雪莲花中含有的木脂素类化合物的含量及种类虽然较少，但却是雪莲花发挥抗炎、抗氧化、美白生物活性的重要组成部分。

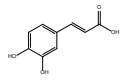
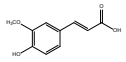
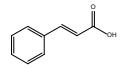
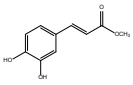
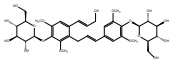
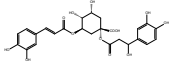
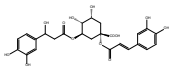
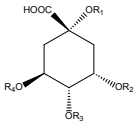
2.5 苯丙酸及其衍生物化合物

苯丙酸及其衍生物在雪莲中广泛存在，其中紫丁香苷被广泛报道。此外，雪莲花中还含有绿原酸，咖啡酸，阿魏酸，以及咖啡酰奎宁酸类化合物[34−38]。

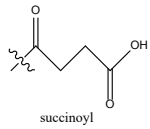
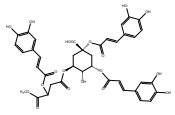
表5 雪莲花中苯丙酸及其衍生物化合物结构与生物活性

序号	结构式	名称	生物活性	文献
1		Syringin	抗氧化、抗炎、抗菌	[130] [130] [131]
2		Chlorogenic acid	抗炎、抗氧化、美白、抗菌	[132] [133] [134] [135]

续表5 雪莲花中苯丙酸及其衍生物化合物结构与生物活性

序号	结构式	名称	生物活性	文献
3		Caffeic acid	抗氧化、抗炎、抗菌、美白	[133] [136] [137] [138]
4		Freulic acid	美白、抗炎、抗氧化、抗老化	[138] [139] [140] [141]
5		Cinnamic acid	美白	[142,143]
6		Methyl caffeate acid	抗炎	[144]
7		Tangshenoside III		
8		丹参素－咖啡酰奎尼酸 a		
9		丹参素－咖啡酰奎尼酸 b		
10		R_1=H R_2=caffeoyl R_3=H R_4=H 3−*O*−caffeoyl−quinic acid	抗氧化、美白、抗炎	[145] [145]
11	caffeoyl	R_1= caffeoyl R_2=H R_3=H R_4=H 1−*O*−caffeoyl−quinic acid		
12		R_1= H R_2=H R_3=H R_4= caffeoyl 5−*O*−caffeoyl−quinic acid	抗氧化、美白、抗炎	[145] [145]
13		R_1= H R_2=H R_3= caffeoyl R_4= H 4−*O*−caffeoyl−quinic acid	抗氧化、美白、	[145] [145]
14		R_1=H R_2=feruloyl R_3=H R_4=H 3−*O*−feruloyl−quinic acid (famprofazone)		
15	feruloyl	R_1=H R_2=H R_3=H R_4=*p*−coumaroyl p−coumaroyl−quinic acid		
16		R_1=caffeoyl R_2=caffeoyl R_3=H R_4=H 1，3−*O*−dicaffeoyl−quinic acid	抗氧化、美白、抗炎	[146] [147]
17		R_1=caffeoyl R_2=H R_3=caffeoyl R_4=H 1，4−*O*−dicaffeoyl−quinic acid	美白、	[147]
18		R_1=caffeoyl R_2=H R_3=H R_4=caffeoyl 1，5−*O*−dicaffeoyl−quinic acid	抗氧化、美白	[146] [147]
19		R_1=H R_2= caffeoyl R_3= caffeoyl R_4=H 3，4−*O*−dicaffeoyl−quinic acid	抗氧化、抗炎、美白	[144] [148] [147]
20	*p*-coumaroyl	R_1=H R_2= caffeoyl R_3=H R_4=caffeoyl 3，5−*O*−dicaffeoyl−quinic acid	抗氧化、抗炎、美白	[144] [148] [147]

续表5 雪莲花中苯丙酸及其衍生物化合物结构与生物活性

序号	结构式	名称	生物活性	文献
21		R_1=H R_2=H R_3= caffeoyl R_4=caffeoyl 4，5−*O*−dicaffeoyl−quinic acid	抗氧化、美白、抗炎	[144] [144] [148]
22		R_1=caffeoyl R_2=succinoyl R3=H R_4=caffeoyl 1，5−dicaffeoyl−3−succinoylquinic acid		
23		R_1=caffeoyl R_2=H R_3=succinoyl R_4=caffeoyl 1，5−dicaffeoyl−4−succinoylquinic acid		
24		R_1= caffeoyl R_2= succinoyl R_3= succinoyl R_4= caffeoyl 1，5−dicaffeoyl−3，4−dis−uccinoylquinic acid		
25		1，3−di−*O*−caffeoyl−5−*O*−(1−methoxyl−2−*O*−caffeoyl−4−maloyl)−quinic acid		

雪莲花中含有众多酚酸类化合物，特别是绿原酸及其二聚体在雪莲花中含量较高，并且具有较强的抗氧化、抗炎、美白活性。

2.6其他类化合物

雪莲花中还含有生物碱如秋水仙碱（colchicine）、吲哚−3−乙酸（3−indolylacetic acid），醌类化合物如大黄素甲醚（physcion），小分子酚酸类化合物如原儿茶酸（protocatechuic acid）、原儿茶醛（3,4−dihydroxybenzaldehyde）等化合物。此外，雪莲中还含有挥发油类成分、多糖、氨基酸、肽类物质以及神经酰胺类物质[34−38]。

进一步对雪莲花发挥生物活性及其对应的关键物质进行了汇总，如表6所示。雪莲花发挥抗炎活性的化学成分，包括倍半萜及其糖苷类、黄酮及其糖苷类、香豆素类、木脂素类、苯丙酸及其衍生物，因此具有较强的抗炎活性，是发挥化妆品功效的基础活性之一。另一方面，黄酮类、苯丙酸及其衍生物类、木脂素、香豆素类化合物由于自身结构含有酚羟基，通过电子转移及供氢作用机制实现清除自由基发挥抗氧化活性。雪莲花还具有防辐射活性，推测这与其生存环境密切相关，由于在高海拔辐射极强的天山山脉，使其富含众多黄酮和酚酸类化合物，通过自身含有的共轭结构，对UVA和UVB都具有较强的吸收特性，具有抗辐射活性的物质基础。雪莲花还含有较为丰富的美白活性成分，并且种类极其丰富，包括黄酮类、香豆素、木脂素和酚酸类化合物，特别是结构多样的咖啡酰奎尼酸类化合物，通过抑制酪氨酸酶的活性及其上游MAPK、PI3K信号通路的调控作用发挥美白功效，因此雪莲花通过“多成分−多靶点−共协同”的作用方式发挥美白功效。

表6 雪莲花提取物中按生物活性有效成分汇总表

生物活性	有效成分
抗炎	倍半萜及其糖苷类、黄酮及其糖苷类、香豆素类、木脂素类、苯丙酸及其衍生物
抗氧化	黄酮及其糖苷类、木脂素类、苯丙酸及其衍生物、香豆素
抗辐射	黄酮类、酚酸类类化合物
美白	芦丁、槲皮素、田蓟苷、圣草酚、蛇床子素、秦皮乙素（七叶内酯）、牛蒡子苷元、牛蒡子苷、绿原酸、咖啡酸、阿魏酸、肉桂酸、3−*O*−咖啡酰奎宁酸、4−*O*−咖啡酰奎宁酸、5−*O*−咖啡酰奎宁酸、1，3−二−*O*−咖啡酰奎宁酸、1，4−二−*O*−咖啡酰奎宁酸、1，5−二−*O*−咖啡酰奎宁酸、3，4−二−*O*−咖啡酰奎宁酸、3，5−二−*O*−咖啡酰奎宁酸、4，5−二−O−咖啡酰奎宁酸

通过对雪莲花化学成分和生物活性文献研究，可以发现在制备雪莲花提取物时，应重点关注对黄酮、酚酸、木脂素、香豆素类化合物等生物活性成分的富集，从而提升雪莲花提取物在化妆品中的功效性。可以进一步选择合适的提取、分离纯化工艺，选择性地去除无效成分，提升雪莲花提取物的生物活性，更好地体现雪莲花提取物对皮肤的有益作用。

3. 总结与展望

雪莲花作为中华九大仙草之一，又名“雪山花王”、“瑶池圣花”。雪莲花生长在其它植物难以驻留的高山雪线之上，长期受到高强紫外辐射和极端严寒生长环境的磨炼，拥有极强的抗逆性，也正是这样独特的生长环境，成就了雪莲花独特的活性物质。例如，雪莲花发挥抗炎活性的关键物质为倍半萜内酯类和黄酮类化合物；其极强的清除自由基的活性，与黄酮、酚酸、苯丙素和木脂素类化合物有关，它们含有的酚羟基可以通过电子转移或氢供体机制，达到抗氧化作用；雪莲花含有的多甲氧基黄酮、多糖、木脂素、酚酸和香豆素类化合物是雪莲花发挥美白功效的关键物质；雪莲花中富含具有共轭吸收结构的黄酮、多酚类物质是其发挥抗辐射活性的关键成分。在此物质基础上，雪莲花通过抵御紫外线辐射防止日光性晒黑，抑制炎症介质释放，解决炎症性色素沉着；其强大的抗氧化作用，还可以通过降低皮肤内ROS的形成和提高GSH−Px的活性，加强真黑素向褐黑素的转变，从而实现抗炎、抗氧

化、美白和抗衰等生物活性，在抗皱、舒缓、祛斑美白、防晒等化妆品中有着巨大的应用潜力。

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Research Progress on the Efficacy of Main Active Ingredients of *Saussurea Involucrate* in Cosmetics

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Abstract： *Saussurea Involucrate* has excellent anti-inflammatory, antioxidant, radiation resistant, and whitening biological activities, making it unique in cosmetics. This is closely related to that *S. Involucrate* is rich in various bioactive substances such as sesquiterpenes, flavonoids, coumarins, phenolic acids, lignans, phenylpropanoids, and polysaccharides. The article summarizes and expounds the research status, biological activities and mechanisms of *S. involucrate* domestic and abroad by reviewing a large number of domestic and foreign literature, providing reference values for the development and utilization of *S. involucrate* in cosmetics.

Keywords： ***saussurea involucrate*; biological activities; chemical components; cosmetics**