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5个意大利酿酒葡萄品种与我国酿酒主栽品种果实品质特性比较

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摘 要：【目的】进一步了解从意大利引进的5个酿酒葡萄品种（‘Corvina’‘Corvinone’‘Garganega’‘Molinara’‘Rondinella’）果实特性。【方法】以5个意大利酿酒葡萄品种和‘赤霞珠685’‘霞多丽277’成熟果实为材料，采用分光光度法和顶空固相微萃取结合气质联用技术分析果实酚类物质含量和挥发性香气成分。【结果】4个红色意大利品种果皮总花色苷含量显著低于‘赤霞珠685’，而‘Molinara’显著低于其他3个品种。‘Corvinone’果皮总酚、单宁和原花色素含量仅次于‘赤霞珠685’，但总类黄酮含量最高；‘霞多丽277’果肉酚类物质含量最高，‘Corvina’次之，‘Corvinone’居第三位；‘Corvina’种子酚类含量最高。7个品种果实挥发性香气成分中，‘Garganega’种类最多，‘Corvina’最少；检测到的7类挥发性香气中，中短链脂肪酸含量最高，醇类次之，乙酸酯最低；有5种香气化合物（癸醛、苯乙醛、β-大马士酮、β-紫罗兰酮和香叶醇）含量超过了阈值，其中苯乙醛气味活性值（odor activity value，OAV）最大；果实花香、焦糖味OAV值分别居第一、第二位，‘Corvinone’‘Molinara’和‘Rondinella’水果香OAV居第三位，而其他4个品种植物味居第三位。【结论】7个品种果实各有特点，也有共同点。根据其酚类物质和香气特点，在杂交培育新的品种时可根据育种目标选择性筛选杂交后代，也可根据各品种特点进行酿造工艺改良。

关键词：酿酒葡萄；引种；果实；酚类物质；挥发性香气

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A comparison of the fruit quality among five wine grape varieties introduced from Italy and two main cultivated varieties in China

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Abstract:【Objective】In order to enrich wine grape germplasm resources, the Pomology Institute, Shanxi Academy of Agricultural Science introduced five wine grape varieties (‘Corvina’ ‘Corvinone’ ‘Garganega’ ‘Molinara’ and ‘Rondinella’) from Italy in 2012. To further understand the features of the five wine grape varieties and provide reference for selection of wine grape varieties, we compared the quality traits of their matured berries with the main cultivated wine grape varieties (‘Cabernet Sauvignon 685’ and ‘Chardonnay 277’).【Methods】The experiments were carried out in 2015 and 2016. The berries were collected from grape vines grown in the vineyards of Pomology Institute, Shanxi Academy of Agricultural Science in Taigu, Shanxi province during September to October in 2015 and 2016. The samples were frozen using liquid nitrogen and stored in an ultra-low temperature freezer. The contents of phenolic compounds were analyzed for 2 years in Pomology Institute, Shanxi Academy of Agricultural Science in Taigu, Shanxi province according to the colorimetric method; while the aromatic

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compounds were determined in the Institute of Forestry and Pomology, Beijing Academy of Agriculture and Forestry Sciences in Beijing in 2016, using headspace solid phase micro-extraction (HS-SPME) and gas chromatography-mass spectrometry (GC-MS) combined with automated mass spectral deconvolution and identification system (AMDIS). 【Results】The results showed that the mature berries of the seven grapes had an average weight between 1.4 g and 3.2 g, with oval or conical shape, and contents of the titratable acid and soluble solids ranged from 0.43% to 0.86% and 19.0% to 27.0%, respectively. 'Molinara' had the highest ratio of peel to pulp. Among the seven varieties, the juice yield of fruit was over 70% in all varieties except 'Chardonnay 277'. The phenolic contents in different parts of berries were significantly different. The total anthocyanin content in the four red wine grapes from Italy was significantly lower than in 'Cabernet Sauvignon 685', and the content in 'Molinara' was significantly lower than that in the other three red ones. 'Cabernet Sauvignon 685' had the highest contents of total phenol, tannin and proanthocyanidin in the peel, followed by 'Corvinone', which had the highest content of total flavonoids. The contents of tannins and proanthocyanidins in 'Garganega' were significantly lower and higher than in 'Chardonnay 277', respectively; the content of total flavonoids in 'Corvina' and 'Rondinella' were significantly lower than the one in 'Cabernet Sauvignon 685'. 'Chardonnay 277' had the highest content of phenolics in the pulp, followed by 'Corvina' and 'Corvinone', and those contents were significantly higher than 'Garganega'. Compared with 'Cabernet Sauvignon 685', 'Molinara' and 'Rondinella' had significantly higher tannin and lower proanthocyanidin contents, while the contents of total flavonoids were significantly and 92.9% higher and 19.0% lower, respectively. The seeds of 'Corvina' had the highest content of phenolics, which were significantly higher than that in 'Cabernet Sauvignon 685', whereas the seeds of 'Rondinella' had the lowest content of phenolics among the five red wine grapes. Compared with 'Cabernet Sauvignon 685', the content of phenolics in 'Corvinone' was significantly higher, while in 'Molinara', only the content of total phenolics was significantly higher. The content of phenolics in 'Garganega' seeds was significantly higher than that in 'Chardonnay 277'. 'Garganega' and 'Corvina' had the most and fewest species of volatile aroma components, respectively. Among the seven kinds of aroma compounds, medium-chain fatty acids were the most abundant, followed by alcohols, and acetates were the lowest. Except for 'Corvinone', the contents of medium-chain fatty acids in the rest of the five varieties were significantly lower than in 'Cabernet Sauvignon 685', while there was no significant difference in the contents among the five varieties. 'Cabernet Sauvignon 685' had the highest content of alcohols, following by 'Chardonnay 277', while the contents in the five Italian varieties were significantly lower than in them, and among the five Italian varieties, 'Corvinone' was the highest while 'Corvina' the lowest. There were six to eight kinds of aroma compounds that exceeded their corresponding threshold, especially the five kinds that werecommon in all varieties, including decanal, phenylacetaldehyde, β-damascenone, β-ionone, and geraniol. Among them, phenylacetaldehyde, which yields the aroma of flowers, roses and honey, had the biggest odor activity value (OAV); β-damascenone generating the aroma of floral, lilac and stewed apple, had the second OAV in 'Corvinone' 'Molinara' 'Rondinella' and 'Chardonnay 277'; while decanal showing the aroma of green and fresh, had the second OAV in 'Corvina' 'Garganega' and 'Cabernet Sauvignon 685'. Among all the aroma compounds exceeding threshold, the common one in 'Corvina' and 'Chardonnay 277' was 2-methoxy-3-isobutyl pyrazine, which shows the aroma of peppery and had the second OAV in 'Corvina'; while the common one in 'Corvinone' 'Cabernet Sauvignon 685' and 'Chardonnay 277' was isobutanol, showing the aroma of fusel, alcohol and green. TDN, which gives the aroma of kerosene, was the common aroma compound in 'Garganega' and 'Rondinella'; α-farnesene, which shows aroma of floral, was the common compound in 'Corvinone' 'Molinara' and 'Rondinella'; the unique aroma compound in 'Cabernet Sauvignon 685' was vitispirane B, which shows the aroma of camphor. The fragrance of flowers with the highest OAV was the most prominent aroma in the berries of the seven grapes, followed by caramel flavor (sweet fragrance). The third fragrance in the berries of 'Corvina' 'Garganega' and 'Chardonnay 277' was vegetal flavor (mainly green pepper and raw green flavor), while that in the other three varieties was fruit flavor.【Conclusion】The seven wine grapes had their own or common characteristics. The phenolics contents in different parts of berries were significantly different among the seven grapes. According to the characteristics of the phenolics and aroma, we can not only select the hybrids according to the target of breeding new varieties of wine grapes, but also improve the brewing according to the characteristics of different varieties.

Key words: Wine grape; Introduction; Berry; Polyphenolic compounds; Volatile aroma

意大利葡萄种植历史可以追溯到公元前2 000 a（年）以前，葡萄树已成为其特有的一道风景线，这一切都得益于意大利得天独厚的地理环境、优越的气候条件和厚重的历史底蕴。意大利也以葡萄品种多而闻名于世，拥有的酿酒葡萄品种数量也远超其他国家，根据意大利农业和林业部的数据，目前意大利有超过350个品种经过认证并被授予法定地位，市面上见到的意大利葡萄品种超过500个[1]。

'Garganega'是意大利东北部威尼托产区的一个古老的白葡萄品种，中晚熟，生长势旺盛，丰产性突出，以酿制苏瓦韦葡萄酒而闻名[2]；红葡萄品种'Corvina'广泛种植于威尼托区和瓦尔伯利塞拉山地区，以及北部和东北部的维罗纳[3]，成熟较晚，生长势旺盛；红葡萄品种'Corvinone'主要种植在威尼托瓦坡里切拉产区[3]，晚熟，虽然与'Corvina'在外表和名称上十分相似，但DNA检测结果显示它们是截然不同的葡萄品种[4]；'Rondinella'是一个产量非常可观的红葡萄品种，主要种植在威尼托产区[3]，深受当地酒农和酒商的喜爱，其亲本之一是'Corvina'[5]；'Molinara'也是起源于威尼托产区的红葡萄品种[3]，但由于颜色浅和极易氧化，很少作为单一品种酿造葡萄酒，'Molinara'在与'Corvina'和'Rondinella'葡萄混酿的时候充当了增加葡萄酒酸度和果香的重要角色[3]。

我国2016年葡萄酒产量达114万t，酿酒葡萄栽培面积达80万hm^2[6]。根据《中国葡萄志》[7]和《葡萄新品种汇编》[8]及文献所报道，1952年到2016年，我国利用常规杂交育种和无性系选种共选育出46个酿酒葡萄优良品种，但是，目前我国酿酒葡萄栽培面积最大的还是国际上种植最普遍的'赤霞珠'。因此，开展酿酒葡萄品种选育和选择日益迫切。选育出具有自主知识产权和适应我国栽培环境的优良加工品种，可以为酿酒葡萄发展提供品种支撑，促进我国葡萄产业的发展，提升我国葡萄酒产品市场的竞争力。在'十二五'期间，山西省农业科学院果树研究所葡萄课题组承担了国家现代农业产业技术体系加工品种选育岗位的工作，主要任务是酿酒葡萄育种，为了丰富酿酒葡萄种质资源，为我国酿酒葡萄品种选育提供参考，本岗位于2012年从意大利维罗纳省果树试验站引入5个酿酒葡萄品种'Corvina''Corvinone''Garganega''Molinara''Rondinella'，2014年开始挂果，目前已经连续观察3 a，在山西晋中地区，5个品种成熟期在9月下旬至10月中下旬。笔者主要分析了这5个酿酒葡萄品种和目前主栽酿酒品种'赤霞珠685''霞多丽277'成熟期果实酚类物质和挥发性香气物质的差异，为这些引进种质的有效开发利用奠定基础。

1　材料和方法

1.1　材料及取样

参试的5个意大利酿酒葡萄品种'Corvina''Corvinone''Garganega''Molinara''Rondinella'均于2012年定植于山西省农业科学院果树研究所（太谷）葡萄育种园，主栽品种'赤霞珠685''霞多丽277'于2010年定植于山西省农业科学院果树研究所（太谷）酿酒葡萄采穗圃，均为倾斜式单龙蔓"厂"字形立架栽培，株行距0.8 m×2.5 m，5个意大利品种于2014年开始结果。于2015年和2016年9—10月果实成熟期连续2 a采集各品种葡萄供试材料，取样时每个品种随机选择4棵树，在树枝中部摘取2~3个

果穗。取样后先进行穗质量、果粒质量、果皮质量、种子质量和果粒纵、横径等果实特性的测量；然后，随机选取一部分果粒测定可溶性固形物含量、可滴定酸含量、出汁率和果汁pH值等品质特性；其余果粒于保鲜袋中置液氮速冻，-80 ℃冰箱保存，在11—12月份在实验室内提取测定果皮、果肉和种子的酚类物质含量。香气成分测定于2016年12月在北京市农林科学院果树研究所进行。

1.2 测定指标及方法

1.2.1 *果实特性* 在果实成熟期（2015年9月25日、2016年10月19日）于试验田间每个品种随机取6个标准果穗，测定果穗质量；然后分果穗剪取全部果粒，随机取30个果粒测定果粒质量、果皮质量、种子质量；再取5个果粒测量果粒纵、横径。

1.2.2 *可滴定酸和可溶性固形物含量* 可滴定酸含量采用指示剂滴定法测定。可溶性固形物含量采用PAL-1型手持袖珍折射仪（上海鑫际仪器有限公司）测定。

1.2.3 *果皮、果肉和种子的酚类物质含量* 参照谭伟等[9]的方法进行提取。将液氮冷冻果粒的果皮、果肉和种子人工剥离，取果皮2 g、果肉6 g、种子2 g，果皮和果肉分别用研钵研磨成浆，用70%（φ，后同）乙醇洗入100 mL容量瓶，保证完全转移入容量瓶；种子直接放于容量瓶中，50 mL 70%乙醇浸泡。室温，超声波25 min，用70%乙醇定容，过滤入棕色试剂瓶，滤液为总酚提取液。总酚、单宁含量采用Folin-Ciocalteu法[10]测定；总类黄酮含量按照氯化铝比色法[10]测定；原花色素含量采用正丁醇-盐酸比色法[11]测定。另外，称取葡萄果皮0.2 g，加入1%（ω）盐酸-无水甲醇提取液20 mL，于室温下暗处浸提12 h，定容至50 mL棕色容量瓶，采用pH示差法测定果皮总花色苷含量[12]。

1.2.4 *果实香气成分* 香气测定在北京市农林科学院果树研究所进行。样品制备、顶空固相微萃取方法和气相色谱质谱条件参考张明霞[13]的方法进行。香气物质定性和定量分析参照孙磊等[14]的方法进行。

1.3 数据分析

果实理化指标数据和酚类物质含量均为2015年、2016年2 a数据的平均值，挥发性香气成分为2016年数据。试验数据采用Microsoft Excel软件进行处理和图表制作，采用SPSS 13.0统计软件进行方差分析、LSD多重比较。

2 结果与分析

2.1 意大利酿酒葡萄品种与我国酿酒主栽品种果实品质性状比较

由表1可以看出，‘Corvinone’‘Rondinella’与‘霞多丽277’果穗较小，平均穗质量在170 g以下，‘赤霞珠685’果穗中等，在200 g左右，其他3个葡萄品种果穗中大，并以白色品种‘Garganega’平均穗质量最大。‘Corvinone’平均果粒质量在1.5 g左右，与‘赤霞珠685’相近；其他4个意大利品种果粒质量均在2.0 g以上，高于‘霞多丽277’，以‘Corvina’最大。果形指数为果粒的纵径与横径之比，7个品种的果形指数均大于0.95，即果实为椭圆形或圆锥形。

7个品种果粒果皮和种子占果实的比重不同，果皮占果实的比重最大、最小的分别是‘Molinara’

表1 7个酿酒葡萄品种成熟期果实特性

Table 1 The fruit characteristics of the seven wine grape varieties

品种 Variety	平均穗质量 Average cluster mass/g	果粒质量 Average berry mass/g	果粒径 Berry size/cm		果形指数 Fruit shape index	果皮占果实比重 Peel SG/%	种子占果实比重 Seed SG/%	皮肉比 Ratio of peel to pulp	ω(可滴定酸) Titratable acid content/%	ω(可溶性固形物) Soluble solid content/%	出汁率 Juice yield/%
			纵径 Longitudinal diameter	横径 Transverse diameter							
Corvina	345.8	3.14	2.042	1.794	1.14	18.04	2.96	0.228	0.853	23.08	70.90
Corvinone	135.1	1.48	1.480	1.260	1.17	18.93	5.27	0.250	0.801	26.80	71.56
Garganega	490.0	2.46	1.484	1.530	0.97	23.58	2.34	0.318	0.539	22.36	76.32
Molinara	282.9	2.89	1.696	1.668	1.02	31.92	4.31	0.501	0.436	19.10	73.14
Rondinella	168.4	2.05	1.512	1.464	1.03	25.06	4.10	0.354	0.673	21.02	76.70
赤霞珠685 Cabernet Sauvignon 685	203.6	1.41	1.340	1.266	1.07	24.33	11.81	0.381	0.751	21.52	72.18
霞多丽277 Chardonnay 277	150.2	1.72	1.454	1.382	1.06	21.98	6.31	0.307	0.771	21.58	68.41

和'Corvina'，种子占果实的比重最大、最小的分别是'赤霞珠685'和'Garganega'。白色品种'Garganega'和主栽品种'霞多丽277'皮肉比（果皮与果肉质量比）相近；红色品种以'Molinara'皮肉比最大，高于主栽品种'赤霞珠685'，其余3个红色品种均低于'赤霞珠685'。

7个品种果实可滴定酸含量（ω，后同）为0.43%~0.86%，'Corvina'和'Corvinone'高于'赤霞珠685'，其余3个意大利品种均低于主栽品种，并以'Molinara'最低；果实可溶性固形物含量（ω，后同）为19.1%~26.8%，其中'Molinara'最低，其他6个品种均在20%以上，'Corvinone'最高。7个品种除'霞多丽277'外果实出汁率均在70%以上。

2.2　意大利酿酒葡萄品种与我国酿酒主栽品种果实酚类物质含量比较

如表2所示，4个红色意大利品种果皮总花色苷含量均显著低于我国主栽品种'赤霞珠685'，其中'Molinara'中的含量又显著低于其他3个意大利品种。

表2　7个酿酒葡萄品种成熟期果实酚类物质含量

Table 2 The phenolics contents in fruit of seven wine grapes

($mg \cdot g^{-1}$)

组织 Tissues	酚类物质 Phenolics	品种 Variety						
		Corvina	Corvinone	Garganega	Molinara	Rondinella	赤霞珠685 Cabernet Sauvignon 685	霞多丽277 Chardonnay 277
果皮 Skin	总花色苷 Total anthocyanin	2.580±0.107 b	2.921±0.161 b		1.081±0.134 c	2.997±0.215 b	5.278±0.009 a	
	总酚 Total phenolics	6.181±0.330 c	8.994±0.495 b	6.939±0.339 c	8.307±0.202 b	6.667±0.449 c	10.968±0.534 a	6.868±0.257 c
	单宁 Tannin	5.167±0.266 cd	6.379±0.550 ab	3.423±0.110 e	5.562±0.018 bc	5.419±0.293 bcd	7.275±0.866 a	4.524±0.201 d
	总类黄酮 Total flavonoids	3.001±0.103 d	4.290±0.115 a	3.974±0.080 b	4.258±0.069 a	2.928±0.046 d	3.338±0.199 c	4.198±0.081 ab
	原花色素 Proanthocyanidin	0.701±0.003 e	1.152±0.036 b	0.658±0.016 e	0.857±0.020 d	0.981±0.010 c	1.399±0.026 a	0.387±0.009 f
果肉 Flesh	总酚 Total phenolics	0.470±0.022 b	0.419±0.013 b	0.242±0.004 c	0.242±0.026 c	0.240±0.010 c	0.271±0.016 c	0.571±0.080 a
	单宁 Tannin	0.308±0.022 a	0.290±0.023 a	0.185±0.017 b	0.162±0.021 bc	0.172±0.006 b	0.100±0.024 c	0.329±0.061 a
	总类黄酮 Total flavonoids	0.171±0.000 b	0.168±0.004 b	0.087±0.004 c	0.162±0.004 b	0.068±0.000 d	0.084±0.005 c	0.233±0.009 a
	原花色素 Proanthocyanidin	0.026±0.000 a	0.021±0.001 bc	0.014±0.000 e	0.019±0.000 cd	0.016±0.000 de	0.022±0.003 b	0.027±0.000 a
种子 Seed	总酚 Total phenolics	7.454±0.295 a	2.619±0.105 c	3.905±0.009 b	1.671±0.141 d	0.368±0.020 g	1.215±0.070 e	0.927±0.051 f
	单宁 Tannin	5.152±0.027 a	1.828±0.048 b	1.640±0.156 c	1.202±0.072 d	0.100±0.020 f	1.182±0.081 d	0.800±0.051 e
	总类黄酮 Total flavonoids	4.656±0.259 a	1.476±0.103 c	2.831±0.092 b	0.958±0.057 d	0.512±0.000 e	1.199±0.326 cd	0.428±0.018 e
	原花色素 Proanthocyanidin	0.432±0.049 a	0.207±0.009 c	0.287±0.026 b	0.113±0.003 de	0.064±0.002 ef	0.123±0.001 d	0.034±0.002 f

注：不同小写字母表示同一指标不同品种间差异显著($p < 0.05$)。下同。

Note: Different small letters indicate significant difference among varieties in the same index at 0.05 level. The same below.

5个意大利品种果皮总酚含量均显著低于对照'赤霞珠685'；'Corvinone'和'Molinara'中含量显著高于'Corvina''Rondinella''Garganega'和'霞多丽277'。红色品种中，对照'赤霞珠685'果皮单宁含量最高，与'Corvinone'差异不显著，但显著高于其他5个品种；'Corvina''Molinara'和'Rondinella'单宁含量分别比'Corvinone'低19.0%、12.8%、15.0%，而三者之间差异不显著；白色品种'Garganega'中单宁含量最低，比对照'霞多丽277'低24.3%。'Corvinone'和'Molinara'总类黄酮含量分别比'赤霞珠685'高28.5%和27.6%，而'Corvina'和'Rondinella'总类黄酮含量分别比'赤霞珠685'低10.1%、12.3%；'Garganega'总类黄酮含量与'霞多丽277'差异不显著。原花色素含量由高到低为：'赤霞珠685'＞'Corvinone'＞'Rondinella'＞'Molinara'＞'Corvina'和'Garganega'＞'霞多丽277'。

白色品种'霞多丽277'果肉酚类物质含量最高，显著高于意大利白色品种'Garganega'；其次是红色品种'Corvina'，两者单宁和原花色素含量差异不显著。红色品种中，'Corvina'和'Corvinone'总酚含量显著高于'Molinara''赤霞珠685'和'Rondinella'；'Corvina''Corvinone''Rondinella'和'Molinara'单宁含量分别比'赤霞珠685'高208%、190%、72%、62%，'Rondinella'和'Molinara'单宁含量显著低于'Corvina'和'Corvinone'，但两者之间差异不显

著；‘赤霞珠685’总类黄酮含量显著低于‘Corvina’‘Corvinone’和‘Molinara’，但显著高于‘Rondinella’。‘Corvina’果肉原花色素含量比‘赤霞珠685’高18.2%，而‘Corvinone’‘Molinara’和‘Rondinella’分别比‘赤霞珠685’低4.5%、13.6%、27.3%。

‘Corvina’种子酚类物质含量显著高于其他6个品种。红色品种中，‘Corvinone’种子酚类物质含量显著高于‘Molinara’和‘Rondinella’，总酚、单宁、原花色素和总类黄酮含量比‘赤霞珠685’分别高115.6%、54.7%、68.3%、23.1%；‘Molinara’总酚含量显著高于‘赤霞珠685’，单宁、总类黄酮和原花色素含量则与‘赤霞珠685’差异不显著，且总酚、单宁和总类黄酮含量显著高于‘Rondinella’；‘Rondinella’酚类物质含量显著低于‘赤霞珠685’。白色品种‘Garganega’种子酚类物质含量显著高于对照‘霞多丽277’。

2.3 意大利酿酒葡萄品种与我国主栽品种果实挥发性香气成分种类和含量比较

成熟时测定了7个酿酒葡萄品种果实中挥发性香气成分。白色品种‘Garganega’香气成分种类最多，红色品种‘Corvina’最少，‘Corvinone’‘Rondinella’和‘霞多丽277’香气成分均为81种（表3）。7类挥发性香气化合物中，以中短链脂肪酸含量最高，醇类次之，乙酸酯含量最低。‘Corvinone’中短链脂肪酸含量与‘赤霞珠685’差异不显著，而除‘Corvinone’外的其余5个品种中短链脂肪酸含量均显著低于‘赤霞珠685’，但与‘Corvinone’差异不显著。醇类含量以红色品种‘赤霞珠685’最高，白色品种‘霞多丽277’次之，5个意大利品种均显著低于对照品种，其中‘Corvinone’和‘Garganega’＞‘Molinara’＞‘Rondinella’＞‘Corvina’。单萜和降异戊二烯物质含量在‘Molinara’7类挥发性香气成分中居第三位，而其他6个品种中醛类物质含量居第三位；红色品种中，以‘Molinara’单萜和降异戊二烯物质含量最高，显著高于‘Corvinone’和‘Rondinella’，仅‘Corvina’显著低于对照‘赤霞珠685’，白色品种‘Garganega’和对照‘霞多丽277’差异不显著。‘Corvinone’和‘Corvina’醛类物质含量分别是‘赤霞珠685’的6.4和7.8倍，而‘Molinara’醛类物质含量比‘赤霞珠685’低33.9%。‘Corvinone’‘Corvina’‘Rondinella’‘赤霞珠685’和‘霞多丽277’中单萜和降异戊二烯物质含量在7类挥发性香气成分中居第四位，而‘Garganega’和‘Molinara’中乙醇酯含量居第四位；‘Corvinone’‘Rondinella’‘赤霞珠685’和‘霞多丽277’中乙醇酯含量显著低于‘Garganega’和‘Molinara’，但显著高于‘Corvina’。除‘Molinara’中醛类、‘Garganega’中单萜和降异戊二烯、‘Rondinella’中乙醇酯含量在7类挥发性香气成分含量中居第五位外，另外4个品种中以其他含量居第五位；7个葡萄品种其他类香气成分由高到低为：‘Corvinone’＞‘赤霞珠685’＞‘Garganega’＞‘Corvina’和‘霞多丽277’＞‘Rondinella’和‘Molinara’。

在检出的挥发性香气化合物中，7个葡萄品种中有6~8种含量超过了阈值（即OAV＞1）（表4），共

表3 7个酿酒葡萄品种果实各类香气化合物含量和香气成分种类

Table 3 The aroma compound contents and composition in the seven wine grapes

香气成分 Aroma compounds	Corvina	Corvinone	Garganega	Molinara	Rondinella	赤霞珠685 Cabernet Sauvignon 685	霞多丽277 Chardonnay 277
ρ(中短链脂肪酸) MCFAs content/(μg·L^{-1})	69 189.55 b	70 176.22 ab	68 748.73 b	68 961.02 b	69 026.76 b	72 182.34 a	69 511.37 b
ρ(乙醇酯) Ethyl esters content/(μg·L^{-1})	12.19 c	25.02 b	139.16 a	126.25 a	27.22 b	32.55 b	25.03 b
ρ(乙酸酯) Acetate esters content/(μg·L^{-1})	3.00 d	3.80 c	4.38 b	3.63 c	3.79 c	4.91a	4.04 b
ρ(醇类) Acohols content/(μg·L^{-1})	8 935.17 f	40 701.25 c	38 628.72 c	30 847.60 d	18 903.34 e	76 732.72 a	54 080.61 b
ρ(醛类) Aldehydes content/(μg·L^{-1})	1 160.86 b	1 414.32 a	763.04 c	120.42 f	187.86 e	182.16 e	352.32 d
ρ(单萜和降异戊二烯) Monoterpenes and norisoprenoids content/(μg·L^{-1})	86.90 d	114.19 b	89.85 cd	144.37 a	105.19 b	92.31 c	92.72 c
ρ(其他) Others content/(μg·L^{-1})	33.07 d	65.08 a	47.72 c	24.32 e	26.34 e	55.66 b	39.46 d
香气成分种类 Aroma composition categories	72	81	87	78	81	75	81

表4　香气值、香气描述及香气系列

Table 4 Odor active values, odor description and aromatic series

化合物 Compounds	阈值 Thres-hold/ (μg·L-1)	参考文献 Refer-ence	香气类型 Aroma series	香气描述 Aroma descriptor	品种 Variety						
					Corvina	Corvinone	Garganega	Molinara	Rondinella	赤霞珠685 Cabernet Sauvignon 685	霞多丽277 Chardon-nay 277
癸酸乙酯 Ethyl decanoate	200	[15]	1	水果，愉悦的 Fruity, pleasant			0.56	0.56			
乙酸苯乙酯 2-phenethyl acetate	250	[16]	8	愉悦的，花香，果香 Pleasant, floral, fruity	0.01	0.01	0.01	0.01	0.01	0.01	0.01
水杨酸乙酯 Ethyl salicylate	84	[17]	2	青冬味、薄荷味 minty	0.13	0.13	0.13	0.13	0.13	0.14	0.13
壬醛 Nonanal	1	[18]	1	柑橘 Citrus		0.06		0.72	0.15	0.18	0.26
癸醛 Decanal	0.1	[18]	2	青草，新鲜的 Green, fresh	14.67	14.81	14.78	14.72	14.66	15.03	15.01
苯乙醛 Phenylacetaldehyde	1	[19]	4，8	花香、玫瑰花香，蜂蜜香 Floral, rose, honey	90.85	76.29	86.36	61.62	86.72	63.55	49.90
苯甲醛 Benzaldehyde	2 000	[20]	3，9	烘烤味，杏仁味 Roast, almond	0.01	0.01	0.01	0.01	0.01	0.01	0.01
β-大马士酮 β-damascenone	0.05	[16]	1，8	花香，紫丁香，煮苹果香 Floral, lilac, stewed apple	8.55	28.94	5.46	15.02	27.47	5.53	43.18
α-紫罗兰酮 α-ionone	2.6	[15]	8	花香，紫罗兰 Floral, violet	0.15	0.17	0.15	0.17	0.17	4.12	4.72
β-紫罗兰酮 β-ionone	0.09	[15]	8	玫瑰花香，紫罗兰 Floral, violet	5.47	5.05	6.29	5.58	5.00	9.70	5.12
Vitispirane A	0.5	[21]	6	樟脑味Camphor	0.01	0.04	0.11	0.02	0.13	0.11	0.02
Vitispirane B	0.5	[21]	6	樟脑味Camphor	0.01	0.05	0.01	0.02	0.14	11.65	0.02
TDN	0.02	[22]	6	煤油味Kerosene	0.04	0.97	12.32		1.30		0.66
香叶基丙酮 Geranyl acetone	60	[21]	1	水果香Fruity	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
α-萜品醇 a-Terpineol	250	[15]	8	百合花香 Lily, floral	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
里那醇 Linalool	25.2	[15]	1，8	玫瑰，花香，水果，甜香 Rose, floral, fruity, sweet	0.02	0.29	0.02	0.02	0.06	0.02	0.05
香叶醇 Geraniol	30	[16]	8	玫瑰香，天竺葵花香 Rose, geranium	1.19	1.42	1.14	1.40	1.24	1.17	1.33
香茅醇 Citronellol	100	[16]	8	玫瑰 Roses	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01
橙花醇 Nerol	400	[23]	1	清香，果香Fresh, fruity	0.08	0.08	0.08	0.08	0.08	0.08	0.08
橙花叔醇 Nerolidol	＞100	[24]	1，8	花香，水果，柑橘，柔和香味 Floral, fruity, citrus, light flavor			0.01				
金合欢醇 α-farnesene	20	[25]	8	花香气味 Floral	0.72	1.25	0.86	3.25	1.39	0.73	0.65
柠檬烯 Limonene	10	[26]	1，2，8	花香，青草，柑橘 Floral, grass, citrus	0.06	0.08	0.06	0.06	0.06	0.06	0.06
月桂烯 Myrcene	15	[17]	11	香脂气味 Scent of balsam	0.05	0.06	0.05	0.05	0.05		0.05
顺式-玫瑰醚 *Cis*-rose oxide	0.5	[26]	8	玫瑰 Roses		0.10	0.07	0.14	0.13	<0.01	
反式-玫瑰醚 *Trans*-rose oxide	0.5	[26]	8	玫瑰 Roses		0.03		0.06	0.05		
异丁酸 Isobutyric acid	2 300	[15]	7	奶油，奶酪味，酸腐味 Butter, cheese, rancid	<0.01		<0.01		<0.01		

表4（续） Table 4（continued）

化合物 Compounds	阈值 Threshold/ (μg·L-1)	参考文献 Reference	香气类型 Aroma series	香气描述 Aroma descriptor	品种 Variety Corvina	Corvinone	Garganega	Molinara	Rondinella	赤霞珠685 Cabernet Sauvignon 685	霞多丽277 Chardonnay 277
丙酸 Methylacetic acid	8 100	[15]	7	刺激的酸腐味 Spicy, acid, rancid	0.02	0.03	0.03	0.03	0.03	0.02	0.02
丁酸 Butanoic acid	10 000	[16]	7	奶酪，不新鲜的 Cheese, rancid	0.01	<0.01	0.01	0.01	<0.01	<0.01	<0.01
己酸 Hexanoic acid	420	[15]	7	脂肪，奶酪，不新鲜的 Fatty, cheese, rancid	0.23	0.38	0.41	0.24	0.28	0.29	0.34
辛酸 Octanoic acid	500	[15]	7	脂肪，不新鲜的，刺激，奶酪 Fatty, rancid, harsh, cheese	0.20	0.20	0.20	0.20	0.20	0.20	0.20
癸酸 Decanoic acid	1 000	[15]	7	不新鲜的，奶酪 Rancid, cheese	0.08	0.08	0.08	0.08	0.08	0.08	0.08
异戊酸 Isovaleric acid	33.4	[15]	7	泡菜味、腐败味 Kimchi, rancid			0.21		0.21		
4-乙基愈创木酚 4-Ethy-guaiacol	33	[16]	9，11	烤面包香，烟熏味，丁香味 Spicy, clove		0.36	0.36		0.36	0.19	0.26
4-乙基苯酚 4-Ethyl phenol	440	[27]	7	动物味，马厩味 Animal, stable		0.04	0.04			0.03	
己醇 Hexan-1-ol	8 000	[15]	2	青草味，生青味 Green, grass				0.02		0.03	0.04
苯乙醇 Phenylethanol	14 000	[15]	8	玫瑰，花香 Roses, flower	0.01	0.01	0.01	0.01	0.02	0.02	0.02
1-丙醇 1-Propanol	306 000	[20]	1，6	酒精味，成熟果香 Alcohol, fruity	<0.01	<0.01	<0.01	<0.01	<0.01		<0.01
异丁醇 Isobutyl alcohol	40 000	[16]	2，6	杂醇，酒精味，生青味 Fusel, alcohol, green	0.22	1.01	0.96	0.76	0.46	1.90	1.34
癸醇 Decan-1-ol	400	[15]	8，7	橙花，特殊的脂肪味 Orange, fatty	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
顺式-3-己烯醇 (*Z*)-3-hexen-1-ol	400	[16]	2	青香、药草香和绿叶香 Green, grass	0.05	0.07	0.03	0.02	0.09	0.32	0.06
苯甲醇 Benzyl alcohol	200 000	[20]	1，9	烘烤味，果香 Roasted, fruity	<0.01	<0.01	<0.01	<0.01	<0.01	0.31	0.38
反式-3-己烯醇 (*E*)-3-hexen-1-ol	1 000	[28]	2	青草味，生青味 Green, grass	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01
反式-2-己烯醇 (*E*)-2-hexen-1-ol	15 000	[28]	2	青草味，生青味 Green, grass	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
丁醇 Butanol	150 000	[20]	6	药味，酒精味 Medicinal, alcohol	<0.01	<0.01	<0.01	<0.01	<0.01		<0.01
戊醇 Pentanol	64 000	[29]	6，7	苦杏仁味，香脂味 Bitter almond, balmy		<0.01					
乙偶姻 Acetoin	150 000	[15]	7	奶油味，脂肪味 Buttery, fatty	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
2-甲氧基-3-异丁基吡嗪(IBMP) 2-methoxy-3-isobutyl pyrazine	0.002	[30]	2	青椒味 Peppery	60.28						29.95
反式-橡木内酯 *Trans*-oak lactone	32	[31]	10	椰子香 Coconut			0.16				
顺式-橡木内酯 *Cis*-oak lactone	74	[31]	10	椰子香 Coconut	0.06	0.07	0.09	0.07	0.07	0.07	0.07
5-甲基糠醛 Methyl furfural	16 000	[31]	1，10	香料味，烤杏仁味 Spicy, roasted almond			<0.01				

注：OAV＜0.01 的物质 OAV 数值均显示为＜0.01；1.水果香；2.植物味；3.干果香；4.焦糖味；5.霉土味；6.化学味；7.脂肪味/奶油味；8.花香；9.烘烤味；10.橡木味；11.香料味。

Note: The compound of which the OAV < 0.01 displayed as < 0.01; 1. Fruity；2. Plants；3. Dry fruit；4. Caramel flavor；5. Mildew earthy；6. Chemical；7. Fatty/cream flavor；8. Floral；9. Roasted；10；Oak；11. Spicy.

有的5种超过阈值的香气化合物分别是癸醛、苯乙醛、β-大马士酮、β-紫罗兰酮和香叶醇，其中苯乙醛OAV值最大，呈现花香、玫瑰花香和蜂蜜香，其次是癸醛，呈青草味，香叶醇OAV值最低，呈玫瑰花香、天竺葵花香。在超过阈值的香气化合物中，‘Corvina’和‘霞多丽277’共有的是2-甲氧基-3-异丁基吡嗪，呈青椒味；‘Corvinone’‘赤霞珠685’和‘霞多丽277’共有的是异丁醇，具有酒精味和生青味；‘赤霞珠685’和‘霞多丽277’共有的是α-紫罗兰酮，具有玫瑰花香、紫罗兰味；‘Garganega’和‘Rondinella’共有的是TDN，具有煤油味；‘Corvinone’‘Molinara’和‘Rondinella’共有的是金合欢醇，具有花香气味；‘赤霞珠685’特有的是Vitispirane B，呈樟脑味。这些超过阈值的香气化合物能够改变葡萄酒的香气特点和轮廓[16]。如表5所示，7个品种果实挥发性香气均以花香特征最突出，OAV值最大，其次是焦糖味（甜香味），‘Corvina’‘Garganega’‘赤霞珠685’和‘霞多丽277’中植物味（主要是青椒味、生青味）OAV值居第三位，其他3个品种则是水果香味OAV值居第三位。‘Corvina’和‘霞多丽277’水果香味OAV值居第四位，‘Corvinone’‘Molinara’和‘Rondinella’是植物味OAV值居第四位，而‘Garganega’和‘赤霞珠685’是化学味居第四位。7个品种果实干果香、脂肪味/奶油味、烘烤味、橡木味和香料味OAV值均低于1。

表5　7个酿酒葡萄品种果实香气系列OAV值

Table 5 The flavor series OAV value in seven wine grapes

编号 Code	香气系列 Flavorseries	品种 Variety						
		Corvina	Corvinone	Garganega	Molinara	Rondinella	赤霞珠685 CabernetSauvignon 685	霞多丽277 Chardonnay 277
1	水果香 Fruity	8.72	29.45	6.19	16.46	27.83	6.19	44.02
2	植物味 Plants	75.41	16.11	15.96	15.72	15.41	17.48	46.59
3	干果香 Dryfruit	0.01	0.01	0.01	0.01	0.01	0.01	0.01
4	焦糖味 Caramelflavor	90.85	76.29	86.36	61.62	86.72	63.55	49.90
6	化学味 Chemical	0.27	2.07	13.40	0.81	2.04	13.66	2.03
7	脂肪味/奶油味 Fatty	0.54	0.73	0.98	0.55	0.80	0.63	0.65
8	花香 Floral	107.03	113.66	100.47	87.36	122.34	84.92	105.06
9	烘烤味 Roasted	0.01	0.37	0.37	0.01	0.37	0.51	0.64
10	橡木味 Oak	0.06	0.07	0.24	0.07	0.07	0.07	0.07
11	香料味 Spicy	0.05	0.42	0.41	0.05	0.41	0.19	0.31

3 讨　论

山西省农业科学院果树研究所从意大利引进的5个酿酒葡萄品种，成熟期、果实品质各异，果粒质量1.4~3.2 g，可溶性固形物含量19.1%~26.8%，出汁率70%~77%，均达到酒用葡萄良种含糖量16%~17%、出汁率70%上的要求[32]。酚类物质含量是葡萄品种固有的标记[33-34]，品种间含量差异主要由品种本身、遗传等因素决定[35]。5个意大利葡萄品种与2个我国主栽品种之间果实酚类物质含量有差异，但果皮和种子中总酚占果实总酚含量的90%以上，这与酚类物质主要分布在叶片、种子和果皮中，果肉中含量很少[36-38]的结果一致。张娟等[39]分析了20个红色酿酒品种酚类物质含量，结果显示，葡萄皮（以鲜质量计）中总酚含量（ω，后同）为12~125 mg· 100 g^{-1}，葡萄籽中总酚含量为17~456 mg· 100g^{-1}，果肉中总酚含量为1.24~3.24 mg · 100 g^{-1}。赵文杰等[40]对不同品种的葡萄皮、籽中多酚物质含量进行分析，结果发现不同品种葡萄皮中多酚含量范围为13.8~47.1 mg · g^{-1}，葡萄籽中多酚的含量范围为12~103 mg · g^{-1}。本研究中7个葡萄品种果皮总酚含量为6.181~10.968 mg · g^{-1}，葡萄籽中为0.368~7.454 mg · g^{-1}，果肉中为0.240~0.571 mg · g^{-1}，‘Corvina’种子中的总酚含量高于果皮和果肉，其他6个品种均是果皮中的总酚含量高于种子和果肉。根据5个意大利酿酒葡萄品种酚类物质的特点，在杂交培育新的酿酒品种时可以根据目标选择性筛选杂交后代，又可以根据各品种特点进行酿造工艺改良。在意大利，‘Corvina’‘Rondinella’和‘Molinara’经常混合来酿造瓦尔波里塞拉酒和巴多利诺酒；‘Corvinone’也是与其他葡萄品种混酿；‘Garganega’则与‘Trebbianno di Soave’‘霞多丽’混合酿制干白或甜白。

葡萄果实中的香气物质分别以游离态和糖苷结合态形式存在，笔者主要测定果实挥发性香气成分，

即游离态香气，其种类、含量、感觉阈值及其之间的相互作用决定葡萄和葡萄酒的风味，研究挥发性香气成分对品质育种和确定其酿造工艺均具有重要意义。中短链脂肪酸具有奶酪、刺激、脂肪味香气特点，在葡萄酒中含量较高时，会败坏酿酒香气[41]，本研究中，中短链脂肪酸是7个酿酒葡萄品种果实挥发性香气成分中浓度最大的一类化合物，但均未超过香气阈值。乙醇酯可以赋予葡萄酒果香、花香和甜香气，是葡萄酒重要的香气物质[24, 41]，7个葡萄品种果实中以'Garganega'和'Molinara'乙醇酯浓度最高，'Garganega'的典型香气是成熟水果、白花、杏仁、柑橘类水果和金苹果气息，'Molinara'的典型香气是红樱桃。单萜和降异戊二烯赋予葡萄和葡萄酒特殊的品种香气，对葡萄和葡萄酒的品质具有重要的贡献[42-43]，7个品种以'Molinara'单萜和降异戊二烯浓度最高，'Corvinone'和'Rondinella'次之，'Corvina'和'Garganega'最低，其中共同检出的属于该类香气成分的β-大马士酮、β-紫罗兰酮、香叶醇均超过阈值，赋予果实花香味，另外'Corvinone''Molinara'和'Rondinella'还共同检测到超过阈值的金合欢醇，也具有花香气味。酿酒葡萄果实中醛类物质的种类和含量在总香气化合物中占有较大的比重，苯乙醛、癸醛是7个品种中共同检出的超过阈值的香气成分，分别赋予果实花香、甜香味和青草味。与其他5个品种不同，'Corvina'和'霞多丽277'中另一主要香气活性成分是2-甲氧基-3-异丁基吡嗪，属于吡嗪类，赋予葡萄和葡萄酒青椒味，被认为是'赤霞珠''长相思'等的典型品种香气成分[44-45]。总之，7个酿酒葡萄品种果实的挥发性香气成分能同时引起嗅觉和味觉，主要是花香、甜香。

4 结 论

5个意大利酿酒葡萄品种与2个我国主栽品种果实品质各有特点，也有共同点。4个红色品种果皮总花色苷含量均显著低于'赤霞珠685'；'Corvinone'果皮总酚、单宁和原花色素含量仅次于'赤霞珠685'，但其果皮总类黄酮含量最高；'霞多丽277'果肉酚类物质含量最高，'Corvina'次之；'Corvina'种子中酚类物质最高，'Rondinella'中单宁含量最低。7个品种果实挥发性香气成分有显著差异，其中共有的超过阈值的香气成分有5种，苯乙醛OAV最大，其次是癸醛；花香和甜香是7个品种果实最主要的香气特性，共同检出的苯乙醛、β-大马士酮、β-紫罗兰酮、香叶醇均超过阈值，赋予果实花香味、甜香。'Corvina''Garganega''赤霞珠685'和'霞多丽277'中植物味（主要是青椒味、生青味）OAV值居第三位，其他3个品种则是水果香味OAV值居第三位。

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