

‘赤霞珠’‘梅鹿辄’和‘品丽珠’不同营养系果实与葡萄酒挥发性香气成分分析

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摘要:【目的】为发挥酿酒品种‘赤霞珠’‘梅露辄’和‘品丽珠’不同营养系的优点,筛选香气优良的营养系。【方法】采用顶空固相微萃取结合气质联用技术分析了3个品种共11个营养系成熟果实和葡萄酒中挥发性香气成分。【结果】果实、葡萄酒中香气成分种类分别在64~99种、105~121种,相应的果实与葡萄酒共有成分在60~88种,分为中短链脂肪酸、乙醇酯、醇类、乙酸酯、醛类、单萜和降异戊二烯类、其他7类。除‘赤霞珠’685醇类、191醛类,其余营养系葡萄酒中每类香气浓度均高于果实。果实和葡萄酒中超过阈值的香气成分分别有5种和15种,但不同品种或同一品种不同营养系同一香气气味活性值(OAV值)不同,从而导致其香气特征的差异。‘赤霞珠’685、169和‘梅鹿辄’348果实中苯乙醛、 β -大马士酮OAV值高于其他营养系,与花香、甜香味OAV值最大一致;170果实中2-甲氧基-3-异丁基吡嗪(IBMP)OAV值显著高于191,与其植物味OAV值最高一致,且TDNOAV值最高,与其化学味OAV值最高一致。‘品丽珠’c214果实中IBMP>327>409,赋予c214植物味OAV值>327>409,3个营养系中苯乙醛、 β -大马士酮OAV值趋势与焦糖味、花香味一致。与其他营养系相比,‘赤霞珠’170、338葡萄酒中较高的己酸乙酯、辛酸乙酯、乙酸异戊酯、苯乙醛和 β -大马士酮赋予酒较高的水果味、花香味;‘梅鹿辄’181葡萄酒中较高的辛酸乙酯、己酸乙酯和丁酸乙酯赋予酒较高的水果味、花香味;‘品丽珠’c214中己酸乙酯、丁酸乙酯、乙酸异戊酯OAV值最高,与酒水果味OAV值最高一致,327中IBMP和癸醛OAV值较高,赋予酒植物味高于c214。【结论】根据果实香气特征,‘赤霞珠’685、169、‘品丽珠’327和‘梅鹿辄’348相对较好,根据葡萄酒香气特征‘赤霞珠’338、170、‘梅鹿辄’181和‘品丽珠’409较好。根据其香气特点及市场需要,可进行营养系筛选或酿造工艺改良。

关键词:酿酒葡萄;营养系;果实;葡萄酒;挥发性香气

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Analysis of volatile aroma components in berries and wines of different ‘Cabernet Sauvignon’ ‘Merlot’ and ‘Cabernet Franc’ clones

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Abstract:【Objective】‘Cabernet Sauvignon’, ‘Merlot’ and ‘Cabernet Franc’ are excellent wine grape varieties. Selection of clonal line is one of the main ways for grape breeding. It is of great significance for wine grape selection and promotion to carry out clonal line selection and evaluation on the original good wine grape varieties. The paper aims to take advantage of the merits of ‘Cabernet Sauvignon’,

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‘Merlot’ and ‘Cabernet Franc’ clonal lines, and provide the basis for screening out the clonal line with excellent aromas of berries and wines.【Methods】The mature berries of 5 clonal lines of ‘Cabernet Sauvignon’ (685, 169, 170, 338, 191), 3 clonal lines of ‘Merlot’ (181, 343, 348) and 3 clonal lines of ‘Cabernet Franc’ were used as materials, and the volatile aroma components in berries and wines were analyzed. 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 2016. The samples were frozen using liquid nitrogen and stored in an ultra-low temperature freezer. The wines were made in 2016. The volatile aroma components of the berries and wines were analyzed 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 types and contents of volatile aromas in berries and wines of various varieties were different, and there were differences among the different lines of the same variety. The types of aroma components in the berries and wines of 11 wine grape varieties were 64-99 and 105-121, respectively, and the corresponding components of the berry and wine were 60-88. These aroma components were divided into seven categories including medium-chain fatty acids, alcohol esters, alcohols, acetic esters, aldehydes, monoterpenes and norisoprenoids, ect. Except for the alcohols of ‘Cabernet Sauvignon’ 685 and aldehydes of 191, the concentration of each type aroma components of wine in other lines was higher than that of berry. Among the seven types of aroma compounds, medium-chain fatty acids were mostly abundant, followed by alcohols in the berries, and then by alcohols or ethyl esters in the wines. There were respectively 5-8 and 17-21 types of volatile aroma components in berries and wines exceeding the threshold, and the common ones in 11 wine grape varieties were 5 and 15, respectively. However, the odor activity value (OAV value) of the same aroma component of different varieties or different clonal lines of the same variety was different, which led to differences in their aroma characteristics. Among the medium-chain fatty acids, only hexanoic, octanoic and isovaleric acids in wines exceeded the aroma threshold. The content of alcohol esters in berries of ‘Cabernet Sauvignon’ 191 was highest, while only ethyl caprylate in berries of ‘Cabernet Sauvignon’ 191 exceeded the threshold, which gave the berry banana, pear and flower aroma; in wines, there were six types of esters that exceeded the threshold including ethyl caproate, ethyl caprylate, ethyl butyrate, ethyl acetate, isoamyl acetate, and ethyl lactate, which gave the wine a fruity, floral, creamy and fatty taste. The monoterpenes and norisoprenoids imparted floral aromas to berries and wines, and β -damascone, β -ionone and geraniol in the berries of 11 wine grape lines exceeded the threshold, while only β -damascone and geraniol in wines exceeded the threshold. The phenylacetaldehyde and decanal exceeded the threshold, which gave the berry floral, sweet, and grassy notes, respectively. The OAV values of phenylacetaldehyde and β -damascone in the berries of ‘Cabernet Sauvignon’ 685, 169 and ‘Merlot’ 348 were higher than other clonal lines, which were consistent with the OAV values of floral and sweet aroma in the berries; the OAV value of methoxy-3-isobutylpyrazine (IBMP) in Cabernet Sauvignon 170 was significantly higher than 191, which was consistent with its highest OAV value of plant flavor, and the highest OAV value of TDN was consistent with its highest OAV value of chemical flavor. In berries of ‘Cabernet Franc’ c214, the OAV value of IBMP were higher than that of 327, 409, which gave itself highest plant flavor OAV; and the trend of OAV value of phenylacetaldehyde, β -damastone in 3 clonal lines was consistent with that of caramel flavor and floral aroma. Compared with other clonal lines, the higher ethyl caproate, ethyl caprylate, isoamyl acetate, phenylacetaldehyde and β -damassone in ‘Cabernet Sauvignon’ 170 and 338 wines gave the wine a higher fruit taste and floral aroma; the higher ethyl caprylate, ethyl caproate and ethyl buty-

ate in the wine of ‘Merlot’ 181 gave the wine a higher fruity and floral aroma; in the Cabernet Franc c214, the OAV values of ethyl caproate, ethyl butyrate, and isoamyl acetate were the highest, which was consistent with the highest OAV value of the fruit flavor of the wine. Higher OAV values of IBMP and decanal in 327 gave the wine a higher plant flavor than c214.【Conclusion】According to the aroma characteristics of the berry, ‘Cabernet Sauvignon’ 685 and 169, ‘Merlot’ 348 and ‘Cabernet Franc’ 327 were better, and ‘Cabernet Sauvignon’ 338, 170 ‘Merlot’ 181 and ‘Cabernet Franc’ 409 were better according to the aroma characteristics of wine. According to its aroma characteristics and market needs, brewing process can be improved.

Key words: Wine grape; Clones; Fruits; Wine; Volatile aroma

香气是衡量葡萄和葡萄酒感官品质的重要指标^[1],香气成分的组成与含量决定葡萄和葡萄酒的风味和典型性^[2-3]。葡萄酒中的香气根据其来源可分为品种香、发酵香和陈酿香三大类,其中品种香来源于葡萄果实,在葡萄酒成熟过程中品种香转化形成陈酿香^[4],因此葡萄果实香气成分含量、组成及相互作用决定了葡萄酒的香气^[5]。目前已经鉴定出的葡萄挥发性香气成分大约800多种^[6]。葡萄香气的影响因素有许多,如葡萄属中不同种、品种、营养系、砧木、树龄、成熟度、外部环境(温度、光照、土壤等)等^[7],而品种间遗传基因的差异和砧木的不同等内部因素是决定葡萄浆果香气的先决条件^[8]。不同酿酒品种葡萄果实^[9-12]、葡萄酒^[13-16]香气成分不同,‘赤霞珠’^[17]、‘黑比诺’^[18]、‘霞多丽’^[19]、‘蛇龙珠’^[20]不同营养系果实和葡萄酒香气均有差异。营养系选种是葡萄育种的主要途径之一,世界各葡萄主产国十分重视,许多国家规定不是优良营养系不得繁育种苗^[21]。对原有优良酿酒葡萄品种进行营养系筛选评价,去劣存优,对于酿酒葡萄选种及推广有重要意义。穆宁^[17]通过对‘赤霞珠’3个营养系果实与葡萄酒香气的研究,筛选到了香气、口感最好的是341;张晓^[18]通过对‘黑比诺’4个营养系果实与葡萄酒香气的研究,筛选到了521表现较好。‘赤霞珠’‘梅鹿辄’和‘品丽珠’是国内外公认的酿造红葡萄酒的优良品种,其中前2个品种占中国酿酒葡萄栽培总面积的67%左右。笔者以山西省农业科学院果树研究所种植的‘赤霞珠’5个营养系、‘梅鹿辄’3个营养系和‘品丽珠’3个营养系葡萄果实和葡萄酒中主要挥发性成分进行定量分析,明确各品种、各营养系果实和葡萄酒挥发性成分存在的差异,筛选香气优良的营养系,以期为优良葡萄营养系的推广提供理论指导。

1 材料和方法

1.1 材料及取样

参试的酿酒葡萄品种/营养系‘赤霞珠’(Cabernet Sauvignon)(170、338、191、685、169)、‘品丽珠’(Cabernet Franc)(c214、327、409)和‘梅鹿辄’(Merlot)(348、181、343)均为2009年定植于山西省农业科学院果树研究所(太谷)葡萄园,均为倾斜式单龙蔓“厂”字形立架栽培,株行距0.8 m×2.5 m,于2011年开始结果,每个营养系均为3行,每行约64株树。各营养系葡萄果实2016年9—10月采集,取样时随机采集果穗的顶端、中间和底部各2~3粒浆果,每次重复采集300粒浆果,3次重复,取样后果粒于保鲜袋中置液氮冷冻,-80 ℃冰箱保存。葡萄酒均为2016年酿造,采用常规酿造工艺生产干红葡萄酒,之后入罐中贮藏3个月。于2017年3月份在北京市农林科学院果树研究所进行香气成分的检测。

1.2 果实和葡萄酒香气成分测定分析方法

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^[22]的方法。取-80 ℃冰箱保存的葡萄果实,去梗去籽后约50 g,液氮研磨成粉末状置于50 mL离心管,为防止氧化加入1 g PVPP,室温静置浸渍2 h,7 000 r·min⁻¹离心10 min,取上清液。果实取上述上清液5 mL,葡萄酒样取5 mL分别进行SPME。将样品放入15 mL顶空瓶中,瓶中事先加入1 g NaCl、磁转子,加入10 μL内标(4-甲基-2-戊醇,1.038 8 g·L⁻¹),然后盖上聚四氟乙烯瓶,置于磁力加热搅拌器上40 ℃保持30 min,使用已活化的聚二甲基硅氧烷/碳筛/二乙烯苯(PDMS/CAR/DVB)萃取头40 ℃萃取30 min。气相色谱-质谱仪型号为Agilent

7890GC-Agilent 5975B MS(Agilent, USA);毛细管柱为HP-INNOWAX 60 m × 0.25 mm × 0.25 im(J & W scientific, USA)。固相微萃取手动进样,采用不分流模式,插入气相色谱进样口,进样口温度250 °C,热解析8 min。升温程序:50 °C保持1 min后,升温至220 °C(升温速度3 °C·min⁻¹)保持5 min。质谱接口和离子源温度分别为280 °C、230 °C,电离方式为EI,电离能为70 eV,质量扫描范围为20~350 u。香气物质定性和定量分析方法参照孙磊等^[23]的方法。对于已有标样的香气物质,依据已建立的相同色谱条件下该化合物的保留指数和质谱信息进行定性分析。没有标样的香气物质,利用文献报道中相似色谱条件下该化合物的保留指数以及NIST 11标准谱库(NIST Chemistry WebBook, <http://webbook.nist.gov/chemistry/>)比对结果进行半定性分析。根据葡萄果实样品中香气化合物浓度水平,配制已有香气化合物标样的标准母液,稀释15个不同浓度,建立标准曲线(内标为4-甲基-2-戊醇),根据标准曲线来对已有标样的香气物质进行定量,没有标样的香气物质利用化学结构相似、碳原子数相近的标样香气物质的标准曲线进行半定量。

1.3 数据分析

实验结果为3次重复的平均值。试验数据采用Microsoft Excel软件进行处理和图表制作,采用SPSS13.0统计软件进行方差分析、LSD多重比较。

2 结果与分析

2.1 ‘赤霞珠’‘梅鹿辄’和‘品丽珠’不同营养系果实和葡萄酒香气种类比较

如表1所示,11个酿酒葡萄果实中有64~99种香气成分,葡萄酒有105~121种,相应的果实与葡萄酒共有香气成分有60~88种。*‘赤霞珠’*5个营养系中,果实香气成分种类最多、最少的分别是191、685;葡萄酒香气成分种类最多的是169,而685最少;5个营养系葡萄果实共有香气成分有69种,葡萄酒97种。*‘梅鹿辄’*3个营养系中,343果实香气成分种类最少,343和348葡萄酒香气成分种类比181少1种;3个营养系果实共有香气成分60种,而葡萄酒中99种。*‘品丽珠’*3个营养系中,327果实香气成分种类最多,比c214多1种,327葡萄酒香气成分种类也最多,409最少;3个品系果实共有香气成分62种,而葡萄酒中103种。11份葡萄果实共有香气成分50种,而葡萄酒中93种。

相应的葡萄果实与葡萄酒共有成分中,葡萄酒比果实中含量高的香气成分种类较多,有48~74种,比果实中含量低的香气成分种类有3~22种(表1)。*‘赤霞珠’*5个营养系中,果实和葡萄酒中共有成分最多和最少的分别是191(88种)、685(70种),其中葡萄酒比果实浓度高的分别有74、48种。*‘梅鹿辄’*3个营养系中,果实和葡萄酒中共有成分最多、最少的分别是*‘梅鹿辄’*181(74种)、*‘梅鹿辄’*343(60种),其

表1 11份酿酒葡萄果实与葡萄酒香气成分种类

Table 1 The kinds of aroma components in the fruits and wine of 11 wine grapes

品种 Variety	果实中香 气成分 Aroma components in fruit	葡萄酒中 香气成分 Aroma components in wine	果实和葡萄 酒共有的香 气成分 Common aroma components in fruits and wine	果实中共有成 分 Common aroma components in fruit	葡萄 酒中共有成 分 Common aroma components in wine	葡萄 酒中比果 实含 量高 的香 气成 分 Higher in the wine than in the fruit	葡萄 酒中比果 实含 量低 的香 气成 分 Lower in the wine than in the fruit
赤霞珠685 Cabernet Sauvignon 685	76	105	70	69	97	48	22
赤霞珠191 Cabernet Sauvignon 191	99	113	88			74	14
赤霞珠170 Cabernet Sauvignon 170	89	106	78			59	19
赤霞珠338 Cabernet Sauvignon 338	81	112	76			64	12
赤霞珠169 Cabernet Sauvignon 169	79	114	76			62	14
梅鹿辄181 Merlot 181	80	109	74	60	99	71	3
梅鹿辄343 Merlot 343	64	108	60			48	12
梅鹿辄348 Merlot 348	65	108	62			48	14
品丽珠c214 Cabernet Franc c214	78	114	75	62	103	53	21
品丽珠409 Cabernet Franc 409	70	112	66			53	13
品丽珠327 Cabernet Franc 327	79	121	78			59	19

中葡萄酒中比果实浓度高的分别有71、48种。‘品丽珠’3个营养系中,‘品丽珠’327果实和葡萄酒中共有成分最多,为78种,其中葡萄酒中比果实中浓度高的有59种;‘品丽珠’409果实和葡萄酒中共有成分最少,66种,其中葡萄酒中比果实中浓度高的有53种。

2.2 ‘赤霞珠’‘梅鹿辄’和‘品丽珠’不同营养系果实和葡萄酒香气含量比较

如表2所示,11份葡萄果实和葡萄酒中挥发性

香气成分可以分为中短链脂肪酸、乙醇酯、醇类、乙酸酯、醛类、单萜和降异戊二烯类、其他7类,其中除‘赤霞珠’685醇类、‘赤霞珠’191醛类,其余营养系葡萄酒中香气成分浓度均高于果实。7类香气成分中,中短链脂肪酸浓度最高,果实香气成分中醇类次之,除‘品丽珠’409乙醇酯浓度最低外其他营养系乙酸酯浓度最低;葡萄酒中,除‘赤霞珠’685、191、170和‘梅鹿辄’348乙醇酯浓度居第二位,醇类物质

表2 11份酿酒葡萄营养系果实与葡萄酒挥发性香气成分含量

Table 2 The contents of aroma components in the fruits and wine of 11 wine grape lines ($\mu\text{g}\cdot\text{L}^{-1}$)

材料 Material	品种 Variety	中短链脂肪酸 Medium-chain fatty acid	乙醇酯 Alcohol ester	醇类 Alcohols	乙酸酯 Acetate ester	醛类 Aldehydes	单萜和降异戊二烯类 Monoterpenes and norisoprenoids	其他 Others
果实 Fruits	赤霞珠685 Cabernet Sauvignon 685	80 608.18 \pm 971.67 a	140.23 \pm 0.13 b	77 104.74 \pm 4 009.48 a	5.41 \pm 0.07 a	155.41 \pm 7.16 c	97.26 \pm 1.13 b	79.75 \pm 0.38 a
	赤霞珠191 Cabernet Sauvignon 191	74 005.29 \pm 435 8.15 b	178.29 \pm 14.56 a	45 743.88 \pm 5 709.45 b	4.15 \pm 0.24 b	525.98 \pm 33.58 a	87.53 \pm 0.12 c	76.08 \pm 3.49 b
	赤霞珠170 Cabernet Sauvignon 170	71 178.73 \pm 144.44 b	144.44 \pm 0.30 b	22 732.62 \pm 6 417.03 c	5.58 \pm 0.17 a	148.03 \pm 5.71 c	102.08 \pm 2.72 a	71.18 \pm 0.14 c
	赤霞珠338 Cabernet Sauvignon 338	73 205.19 \pm 3 604.17 b	28.30 \pm 0.49 c	47 756.76 \pm 1 593.48 b	4.23 \pm 0.03 b	216.34 \pm 45.62 b	88.56 \pm 0.42 c	55.96 \pm 0.29 e
	赤霞珠169 Cabernet Sauvignon 169	70 047.89 \pm 158.32 b	25.45 \pm 0.07 c	51 990.80 \pm 4 514.86 b	3.85 \pm 0.05 c	177.03 \pm 24.11 b c	88.80 \pm 0.77 c	59.10 \pm 0.50 d
	梅鹿辄181 Merlot 181	68 883.13 \pm 317.60 c	24.81 \pm 0.00 b	1 832.11 \pm 150.70 a	3.46 \pm 0.02 c	85.62 \pm 10.30 b	88.01 \pm 1.67 a	61.68 \pm 9.04 b
	梅鹿辄343 Merlot 343	82 922.13 \pm 3 302.03 a	24.87 \pm 0.01 b	757.78 \pm 25.75 b	4.00 \pm 0.04 a	107.36 \pm 3.88 a	87.61 \pm 0.14 a	121.82 \pm 3.70 a
	梅鹿辄348 Merlot 348	72 869.81 \pm 556.19 b	32.37 \pm 4.81 a	652.40 \pm 19.74 b	3.78 \pm 0.02 b	86.95 \pm 4.30 b	87.84 \pm 0.42 a	59.92 \pm 14.65 b
	品丽珠c214 Cabernet Franc c214	69 846.30 \pm 185.63 a	24.96 \pm 0.03 b	535.62 \pm 38.15 c	3.70 \pm 0.00 b	168.71 \pm 36.10 a	90.13 \pm 1.73 a	52.27 \pm 1.69 b
	品丽珠409 Cabernet Franc 409	70 620.18 \pm 2 027.79 a	0.50 \pm 0.01 c	4 452.24 \pm 195.13 b	6.14 \pm 0.08 a	69.02 \pm 1.78 b	85.07 \pm 0.87 b	51.92 \pm 0.28 b
	品丽珠327 Cabernet Franc 327	71 077.54 \pm 1 953.86 a	25.17 \pm 0.12 a	18 906.26 \pm 1 888.83 a	3.68 \pm 0.06 b	183.73 \pm 45.92 a	85.57 \pm 0.58 b	55.81 \pm 1.88 a
酒 Wine	赤霞珠685 Cabernet Sauvignon 685	796 644.80 \pm 28 957.16 a	84 184.80 \pm 577.50 ab	33 804.19 \pm 1 183.37 e	834.35 \pm 179.27 e	757.99 \pm 155.16 a	106.13 \pm 1.24 e	1 961.17 \pm 673.99 c
	赤霞珠191 Cabernet Sauvignon 191	483 593.90 \pm 20 707.76 b	68 446.38 \pm 3 572.98 d	54 144.81 \pm 3 074.17 c	1 237.57 \pm 117.32 d	288.01 \pm 56.09 c	114.58 \pm 0.04 c	8 931.76 \pm 596.10 a
	赤霞珠170 Cabernet Sauvignon 170	375 025.30 \pm 1 818.78 c	79 208.48 \pm 5 580.42 bc	45 188.04 \pm 55.40 d	1 514.21 \pm 49.48 c	358.05 \pm 44.22 b c	127.78 \pm 2.78 a	2 007.57 \pm 32.79 c
	赤霞珠338 Cabernet Sauvignon 338	370 998.60 \pm 46 842.26 c	73 696.69 \pm 4 557.05 cd	112 162.37 \pm 159.11 b	2 484.21 \pm 17.61 a	391.28 \pm 14.29 bc	120.08 \pm 0.74 b	6 380.48 \pm 368.93 b
	赤霞珠169 Cabernet Sauvignon 169	475 920.60 \pm 4 003.53 b	90 855.72 \pm 3 384.29 a	147 973.90 \pm 440.72 a	2 134.13 \pm 11.36 b	433.84 \pm 41.91 b	108.91 \pm 0.49 d	1 365.58 \pm 441.45 c
	梅鹿辄181 Merlot 181	492 632.20 \pm 21 914.19 b	57 299.10 \pm 520.48 b	95 094.88 \pm 8 447.82 a	185.13 \pm 28.39 b	205.81 \pm 44.82 c	121.18 \pm 0.66 a	193.73 \pm 12.12 c
	梅鹿辄343 Merlot 343	758 252.80 \pm 66 421.64 a	59 521.87 \pm 5 552.27 ab	96 819.60 \pm 5 095.21 a	66.72 \pm 11.73 c	377.51 \pm 14.61 a	116.29 \pm 0.96 b	2 539.87 \pm 251.48 b
	梅鹿辄348 Merlot 348	567 003.60 \pm 43 337.66 b	67 110.74 \pm 4 406.60 a	57 903.32 \pm 8 03.01 b	357.73 \pm 3.21 a	300.29 \pm 39.36 b	108.24 \pm 0.91 c	5 181.47 \pm 290.02 a
	品丽珠c214 Cabernet Franc c214	420 737.00 \pm 25 698.42 b	22 529.12 \pm 3 993.28 b	73 517.42 \pm 4 366.12 b	1 088.05 \pm 1.07 a	1 493.84 \pm 12.17 a	100.87 \pm 1.04 b	167.84 \pm 4.90 b
	品丽珠409 Cabernet Franc 409	581 453.00 \pm 69 622.44 a	62 697.20 \pm 7 271.29 a	85 635.09 \pm 8 238.35 a	422.99 \pm 69.92 b	219.62 \pm 43.69 c	111.30 \pm 1.31 a	853.79 \pm 271.61 a
	品丽珠327 Cabernet Franc 327	458 511.90 \pm 59 700.40 b	55 689.84 \pm 8 149.26 a	77 327.77 \pm 1 568.32 ab	234.19 \pm 107.64 c	719.67 \pm 36.20 b	96.57 \pm 1.64 c	136.32 \pm 6.90 b

注:不同小写字母表示同一指标同一品种不同品系间差异显著($p < 0.05$)。下同。

Note: Different small letters indicate significant difference among lines of the same variety in the same index at $p < 0.05$. The same below.

居第三,其他营养系醇类物质居第二位,乙醇酯居第三,除‘梅鹿辄’343乙酸酯浓度最低外,其余营养系均是单萜和降异戊二烯浓度最低。

‘赤霞珠’5个营养系果实香气成分中,‘赤霞珠’685中短链脂肪酸浓度最高,其次是‘赤霞珠’191,‘赤霞珠’169浓度最低;‘赤霞珠’191乙醇酯和醛类香气成分最高;‘赤霞珠’685醇类浓度最高,而‘赤霞珠’170乙酸酯、单萜和降异戊二烯浓度最高。葡萄酒中,‘赤霞珠’685中短链脂肪酸和醛类浓度最高,‘赤霞珠’169中乙醇酯和醇类最高,‘赤霞珠’338中乙酸酯最高,‘赤霞珠’191中其他类浓度最高,而‘赤霞珠’170中单萜和降异戊二烯浓度最高。

‘梅鹿辄’3个营养系中,‘梅鹿辄’343果实中短链脂肪酸、乙酸酯、醛类和其他香气浓度显著高于‘梅鹿辄’348和‘梅鹿辄’181,葡萄酒中短链脂肪酸和醛类浓度显著高于‘梅鹿辄’348和181,醇类浓度显著高于‘梅鹿辄’348;‘梅鹿辄’348果实和葡萄酒中乙醇酯、酒中乙酸酯和其他类香气浓度显著高于‘梅鹿辄’343和181;‘梅鹿辄’181果实中醇类显著高于‘梅鹿辄’343和348,葡萄酒中醇类和单萜和降异戊二烯含量显著高于‘梅鹿辄’348。

‘品丽珠’3个营养系中,‘品丽珠’409果实乙醇酯和醛类浓度显著低于‘品丽珠’327和c214,而乙酸酯浓度显著高于后两者;‘品丽珠’327乙醇酯、醇类和其他类含量显著高于‘品丽珠’409和c214。葡萄酒中,‘品丽珠’409中短链脂肪酸、乙醇酯、醇类、单萜和降异戊二烯及其他类香气浓度最高;‘品丽珠’c214乙酸酯和醛类浓度显著高于‘品丽珠’327和409。

2.3 ‘赤霞珠’‘梅鹿辄’和‘品丽珠’不同营养系果实和葡萄酒香气特征比较

如表3所示,11个酿酒葡萄营养系果实中有5~8种挥发性香气成分超过阈值,共有的5种分别是癸醛、苯乙醛、 β -大马士酮、 β -紫罗兰酮、香叶醇,其中苯乙醛香气活性值(OAV)值最大,呈现花香、玫瑰花香和蜂蜜香^[24],呈现玫瑰香、天竺葵花香^[25]的香叶醇OAV值最小,癸醛呈青草味^[26], β -大马士酮呈花香、紫丁香、煮苹果香^[25],而 β -紫罗兰酮呈玫瑰花香、紫罗兰味^[27]。不同品种之间同一种香气成分OAV值有一定差异,且同一品种不同营养系之间也有一定差异。‘赤霞珠’5个营养系共有的超过阈值的香

气成分中,‘赤霞珠’685和169苯乙醛OAV值>170>338>191($p < 0.05$), β -大马士酮显著高于其余3个营养系;‘赤霞珠’170癸醛显著高于‘赤霞珠’685、338和169,与‘赤霞珠’191差异不显著, β -紫罗兰酮>685>191、338、169。‘赤霞珠’1918种超过阈值的香气物质中呈青椒味的2-甲氧基-3-异丁基吡嗪(IBMP)^[28]OAV值最大,显著低于‘赤霞珠’170,其次是苯乙醛、癸醛、 β -大马士酮、辛酸乙酯、 β -紫罗兰酮、香叶醇;‘赤霞珠’685和169中苯乙醛OAV值> β -大马士酮>癸醛> β -紫罗兰酮>香叶醇,前者检测出超出阈值的壬醛,而后者检出呈煤油味^[29]的TDN;‘赤霞珠’170中TDN的OAV值最大,显著高于‘赤霞珠’338和169,其次是IBMP、苯乙醛、Vitispirane B、癸醛、 β -紫罗兰酮、 β -大马士酮;‘赤霞珠’338中苯乙醛OAV值>癸醛> β -紫罗兰酮> β -大马士酮>TDN>香叶醇>异丁醇。‘梅鹿辄’共有5种超过阈值的香气成分,3个营养系癸醛、 β -紫罗兰酮的OAV值差异不显著,‘梅鹿辄’343和348中苯乙醛、香叶醇OAV值显著高于‘梅鹿辄’181,而‘梅鹿辄’348中 β -大马士酮显著高于‘梅鹿辄’181和343;3个营养系中均是苯乙醛OAV值最大,‘梅鹿辄’181和343中癸醛> β -大马士酮> β -紫罗兰酮,‘梅鹿辄’348中则是 β -大马士酮>癸醛> β -紫罗兰酮,且‘梅鹿辄’343和348中呈柑橘味^[26]的壬醛OAV>香叶醇,而‘梅鹿辄’181中未检出壬醛。‘品丽珠’3个营养系共有6种超过阈值的香气成分,IBMP的OAV值最大,且‘品丽珠’c214>327>409($p < 0.05$),其次是苯乙醛,且‘品丽珠’c214和327显著高于‘品丽珠’409;‘品丽珠’c214和409中苯乙醛>癸醛> β -大马士酮> β -紫罗兰酮>香叶醇,而‘品丽珠’327中苯乙醛> β -大马士酮>癸醛> β -紫罗兰酮>香叶醇,且检出超过阈值的TDN;3个营养系中癸醛OAV值差异不显著,‘品丽珠’327中 β -大马士酮、‘品丽珠’c214中香叶醇显著高于其他2个营养系,‘品丽珠’327和c214中 β -紫罗兰酮显著高于‘品丽珠’409。这些超过阈值的香气化合物能够改变果实和葡萄酒的香气特点和轮廓^[25]。如表4所示,‘赤霞珠’5个营养系香气主要有花香味、焦糖味、水果味、植物味、化学味,其中‘赤霞珠’685和169花香味、水果味OAV值显著高于其他营养系,‘赤霞珠’170植物味OAV值>191>685、338和169,化学味OAV值显著高于其他4个营养系;‘赤霞珠’685、338和169挥发性香气特征以花香特征最突出,

表 3 11 个酿酒葡萄营养系果实中主要呈香物质香气值、香气描述及香气系列
Table 3 Odor active values, odor description and aromatic series in fruits of 11 wine grape lines

化合物 Compound	阈值 Threshold/ ($\mu\text{g L}^{-1}$)	香气类型 Aroma series	香气描述 Aroma descriptor	赤霞珠 Cabernet Sauvignon				梅鹿辄 Merlot				品丽珠 Cabernet Franc		
				685	191	170	338	169	181	343	348	c214	409	327
辛酸乙酯 Ethyl caprylate	5 ^[27]	1,8	甜的,花香,水果,香蕉,梨 Sweet, floral, fruit, banana, pear 0.476 a	7.642± 2.318± 0.218 a	15.157± 0.111± 0.014 b	0.244± 0.171± 0.032 b	14.627± 14.895± 0.248 b	14.654± 14.995± 0.031 b	16.104± 16.277± 0.007 b	14.804± 16.127± 0.011 a	14.626± 14.593± 0.068 b	14.660± 14.626± 0.011 a		
壬醛 Nonanal	1 ^[28]	1	柑橘 Citrus	0.476 a	0.218 a	0.014 b	0.032 b	0.031 b	0.163 a	1.424 a	0.181 a	0.001 a	0.046 a	
癸醛 Decanal	0.1 ^[26]	2	青草,新鲜的 Green, fresh	14.642± 0.001 b	15.157± 0.365 ab	0.171± 0.236 a	0.244± 0.248 b	0.031 b	1.643 a	1.424 a	0.181 a	0.001 a	0.046 a	
苯乙醛 Phenylacetaldehyde	1 ^[24]	4,8	花香,玫瑰花香,蜂蜜香 Floral, rose, honey	78.493± 3.584 a	71.160± 9.290 d	55.933± 1.266 b	78.757± 2.364 c	37.919± 5.097 a	45.893± 0.362 b	46.161± 3.287 a	51.541± 2.804 a	41.358± 2.381 b	49.457± 49.457 a	
β -大马士酮 β -damascenone	0.05 ^[25]	1,8	花香,紫丁香,煮苹果香 Floral, lilac, stewed apple	29.605± 3.995 a	8.385± 1.319 b	5.619± 0.005 b	33.548± 0.073 b	11.743 a	12.232± 1.920 b	20.829± 1.202 b	7.031± 2.310 a	5.616± 0.041 b	31.214± 0.259 b	10.765 a
β -紫罗兰酮 β -ionone	0.09 ^[27]	8	玫瑰花香,紫罗兰 Floral, violet	8.462± 0.042 b	6.474± 0.335 c	13.799± 1.395 a	5.609± 0.007 c	5.517± 0.041 c	4.623± 0.044 a	4.599± 0.042 a	4.535± 0.242 a	4.878± 0.064 a	4.575± 0.058 b	4.929± 0.011 a
Vitispirane B	0.5 ^[30]	6	樟脑味 Camphor	0.265± 0.009 b	0.005± 0.001 b	23.194± 4.729 a	0.106± 0.005 b	0.013± 0.002 b	0.005± 0.004 a	0.008± 0.004 a	0.006± 0.003 a	0.006± 0.003 b	0.025± 0.003 a	
1,1,6-三甲基-1,2-二氯萘 IDN	0.02 ^[29]	6	煤油味 Kerosene	0.420± 0.156 b	88.854± 10.802 a	4.840± 0.056 b	1.346± 0.052 b	0.088± 0.012 a	0.008± 0.004 a	0.006± 0.003 a	0.006± 0.003 b	0.006± 0.003 a		
香叶醇 Geraniol	30 ^[25]	8	玫瑰香,天竺葵花香 Rose, geranium	1.393± 0.007 a	1.173± 0.029 c	1.146± 0.001 d	1.194± 0.001 bc	1.203± 0.008 b	1.182± 0.014 b	1.262± 0.006 a	1.276± 0.002 a	1.183± 0.007 a	1.163± 0.006 b	1.168± 0.001 b
异丁醇 Isobutyl alcohol	40 000 ^[28]	2,6	杂醇,酒精味,生青味 Fusel, alcohol,green	1.900± 0.100 a	1.132± 0.142 b	0.523± 0.162 c	1.180± 0.040 b	1.287± 0.113 b	0.006± 0.002 a	0.007± 0.002 a	0.007± 0.007 a	0.006± 0.006 b	0.009± 0.004 b	0.452± 0.048 a
青椒味 Peppery	0.002 ^[28]	2	青椒味 Peppery	61.307± 0.699 b	86.525± 1.166 a	61.525± 1.166 a	59.846± 0.033 c	61.833± 0.133 b	63.525± 1.033 a	59.846± 0.044 b	61.833± 0.048 a	63.525± 0.044 b	61.833± 0.048 a	

表4 11个酿酒葡萄营养系果实香气系列 OAV 值

Table 4 The flavor series of OAV values in fruits of 11 wine grape lines

果实香气系列 Flavor series in fruit	赤霞珠 Cabernet Sauvignon					梅鹿辄 Merlot			品丽珠 Cabernet Franc		
	685	191	170	338	169	181	343	348	c214	409	327
水果味 Fruity	32.800± 3.800 a	16.978± 1.882 b	6.679± 0.021 c	6.154± 0.008 c	33.908± 11.781 a	12.493± 1.940 b	12.903± 1.129 b	22.652± 2.296 a	7.431± 0.035 b	5.819± 0.258 b	31.645± 10.857 a
植物味 Plants	16.933± 0.095 c	77.856± 1.182 b	102.902± 1.131 a	16.735± 0.273 c	16.345± 0.138 c	15.052± 0.010 a	16.507± 1.645 a	16.335± 1.424 a	78.735± 0.657 a	74.766± 0.045 c	77.312± 0.042 b
干果味 Dryfruit	0.010± 0.000 bc	0.037± 0.003 a	0.012± 0.000 b	0.011± 0.000 bc	0.009± 0.000 c	0.008± 0.000 b	0.009± 0.000 a	0.009± 0.000 a	0.008± 0.000 b	0.008± 0.000 b	0.009± 0.000 a
焦糖味 Caramel flavor	78.515± 3.583 a	46.206± 9.290 c	71.182± 1.265 a	55.956± 2.364 b	78.779± 5.097 a	37.941± 0.363 b	45.916± 3.287 a	46.167± 2.804 a	51.563± 2.184 a	41.364± 2.381 b	49.480± 0.657 a
霉土味 Mildew earthy	0.208± 0.042 b		0.364± 0.066 a						0.022± 0.004 a		
化学味 Chemical	2.455± 0.117 b	1.580± 0.017 b	112.764± 6.201 a	6.184± 0.023 b	2.676± 0.159 b	0.111± 0.004 a	0.019± 0.000 c	0.038± 0.007 b	0.025± 0.005 c	0.113± 0.005 b	1.563± 0.072 a
脂肪味/奶油味 Fatty	0.725± 0.022 b	1.018± 0.083 a	0.576± 0.014 c	0.716± 0.013 b	0.669± 0.005 b	0.579± 0.012 a	0.558± 0.000 b	0.542± 0.002 b	0.602± 0.011 b	0.747± 0.019 a	0.611± 0.007 b
花香味 Floral	119.088± 0.290 a	70.965± 7.148 c	92.736± 2.684 b	69.227± 2.421 c	120.120± 16.888 a	57.093± 2.399 c	64.043± 2.100 b	73.725± 0.639 a	65.853± 2.197 b	53.810± 2.753 b	87.756± 11.437 a
烘烤味 Roasted	0.381± 0.000 a	0.399± 0.007 a	0.191± 0.012 b	0.371± 0.000 a	0.365± 0.044 a	0.365± 0.048 a	0.011± 0.001 b	0.010± 0.000 b	0.370± 0.001 a	0.367± 0.002 b	0.369± 0.000 ab
橡木味 Oak	0.074± 0.001 b	0.218± 0.006 a	0.225± 0.029 a	0.075± 0.003 b	0.065± 0.001 b	0.058± 0.001 a			0.064± 0.001 a	0.060± 0.001 b	0.066± 0.002 a
香料味 Spicy	0.473± 0.022 c	0.429± 0.016 c	0.332± 0.023 d	0.687± 0.095 a	0.567± 0.007 b	0.468± 0.067 a	0.081± 0.001 b	0.040± 0.003 b	0.612± 0.076 a	0.379± 0.001 b	0.642± 0.093 a

OAV 值最大,其次是焦糖味,‘赤霞珠’685 和 169 中居于第三位的是水果味,‘赤霞珠’338 中则是植物味居于第三位;‘赤霞珠’191 挥发性香气特征以植物味最突出,OAV 值最大,其次是花香味、焦糖味、水果味;‘赤霞珠’170 则是化学味最重,其次是植物味、花香味、焦糖味。‘梅鹿辄’和‘品丽珠’香气主要有水果、植物、焦糖、花香味,前者 3 个营养系均以花香味最突出,且‘梅鹿辄’348 花香味 OAV 值>343>181($p < 0.05$),其次是焦糖味,且‘梅鹿辄’343 和 348 OAV 值显著高于 181;‘梅鹿辄’181 和 343 中植物味 OAV 值大于水果味,而‘梅鹿辄’348 中相反,且‘梅鹿辄’348 水果味显著高于‘梅鹿辄’181 和 343,而三者植物味 OAV 值差异不显著。‘品丽珠’3 个营养系中,‘品丽珠’327 花香味和水果味 OAV 值显著高于‘品丽珠’c214 和 409,‘品丽珠’c214 植物味 OAV 值>327>409,而‘品丽珠’c214 和 327 焦糖味 OAV 值显著高于‘品丽珠’409;‘品丽珠’c214 和 409 植物味最突出,其次是花香味、焦糖味、水果味,而‘品丽珠’327 中花香味最突出,其次是植物味、焦糖味、水果味。

11 个营养系葡萄酒中有 17~21 种挥发性香气成

分超过阈值,共有的是 15 种(表 5),但不同品种同一物质 OAV 值有差异,且同一品种不同营养系之间也有差异。‘赤霞珠’685、170 和 338 OAV 值居于前五位的香气物质有辛酸乙酯、乙酸异戊酯、 β -大马士酮、苯乙醛和异戊酸,‘赤霞珠’191、169 中居于前五位的香气物质都有辛酸乙酯、乙酸异戊酯、苯乙醛、异戊酸和己酸乙酯。‘赤霞珠’170 和 338 辛酸乙酯显著高于其他 3 个营养系;‘赤霞珠’338 中和乙酸异戊酯 OAV 值>169>170>191>685($p \leq 0.05$), β -大马士酮>170>191、685>169($p \leq 0.05$);‘赤霞珠’169 中苯乙醛、苯乙醇、3-甲硫基丙醇 OAV 值显著高于其他 4 个营养系;‘赤霞珠’170 和 191 己酸乙酯 OAV 值>338>169>685($p \leq 0.05$);‘赤霞珠’191 和 338 中异戊酸 OAV 值>169>170>685($p \leq 0.05$);‘赤霞珠’191 中 β -大马士酮和 TDN 显著高于其他 4 个营养系;‘赤霞珠’685 中丁酸乙酯>191>338、169>170 ($p \leq 0.05$),乳酸乙酯>338、169>170、191($p \leq 0.05$),癸酸显著高于‘赤霞珠’191、170 和 338。

‘梅鹿辄’181 和 343 OAV 值居于前 4 位的香气物质有辛酸乙酯、苯乙醛、异戊酸和己酸乙酯,居于第 5 位的是分别是癸醛和 β -大马士酮;而‘梅鹿辄’

表 5 11个酿酒葡萄品种葡萄酒中主要呈香物质香气值、香气描述及香气系列
Table 5 Odor active values, odor description and aromatic series in wines of 11 wine grape lines

化合物 Compound	阈值 Threshold/ ($\mu\text{g L}^{-1}$)	香气类型 Aroma series	香气描述 Aroma descriptor	赤霞珠 Cabernet Sauvignon				梅鹿辄 Merlot				品丽珠 Cabernet Franc			
				685	191	170	338	169	181	343	348	c214	409	327	
己酸乙酯	14 ^[27]	1	水果, 青苹果, 香蕉 Fruity, green apple, banana	17.65 \pm 0.286 d	34.746 \pm 0.379 a	35.287 \pm 1.687 a	32.331 \pm 0.105 b	19.338 \pm 0.135 c	39.383 \pm 0.799 a	21.187 \pm 0.625 c	25.315 \pm 0.199 b	35.441 \pm 0.093 a	20.761 \pm 1.649 b	21.265 \pm 0.132 b	
Ethyl hexanoate	5 ^[27]	1, 8	甜的, 花香, 水果, 香蕉, 梨 Sweet, floral, fruit, banana, pear	67.96 \pm 0.841 b	50.521 \pm 17.76 b	107.581 \pm 5.875 a	95.204 \pm 0.701 b	62.832 \pm 0.036 a	120.988 \pm 2.041 b	56.444 \pm 0.000 c	7.642 \pm 0.001 b	7.642 \pm 0.001 b	53.927 \pm 0.607 a	53.927 \pm 0.607 a	
辛酸乙酯	20 ^[27]	1	水果 Fruity	13.76 \pm 0.142 a	11.208 \pm 1.861 b	4.409 \pm 0.059 d	7.830 \pm 1.464 c	8.962 \pm 0.035 c	10.910 \pm 1.975 a	6.762 \pm 0.169 b	9.755 \pm 2.009 ab	19.067 \pm 0.013 a	8.904 \pm 1.807 b	2.851 \pm 0.146 c	
Ethyl caprylate	7500 ^[25]	1, 6	水果, 溶剂 Fruity, solvent	1.439 \pm 0.115 c	2.846 \pm 0.373 b	4.035 \pm 0.848 a	1.431 \pm 0.132 c	3.617 \pm 0.573 ab	2.336 \pm 0.257 a	1.572 \pm 0.387 b	2.975 \pm 0.340 a	2.855 \pm 0.532 a	1.725 \pm 0.064 b	1.121 \pm 0.006 b	
丁酸乙酯	14 000 ^[31]	1, 7	奶油香, 果香, 脂肪味 Cream, fruity, fatty	5.168 \pm 0.019 a	3.244 \pm 0.063 c	3.395 \pm 0.054 c	4.314 \pm 0.394 b	4.484 \pm 0.065 b	2.700 \pm 0.363 c	3.138 \pm 0.394 b	3.145 \pm 0.103 b	3.639 \pm 0.210 a	3.604 \pm 0.130 a	3.604 \pm 0.412 a	
Ethyl butanoate	20 ^[27]	1	香蕉, 水果, 梨 Banana, fruity, pear	26.304 \pm 6.012 e	39.576 \pm 3.883 d	49.578 \pm 1.609 c	80.771 \pm 0.505 a	68.422 \pm 0.336 b	5.635 \pm 0.931 b	1.620 \pm 0.406 c	11.316 \pm 0.115 a	35.679 \pm 0.035 a	13.540 \pm 0.2342 b	7.488 \pm 3.585 c	
Ethyl acetate	500 ^[25]	1, 11	辛辣的, 成熟的苹果 Pungent, ripe apple	1.369 \pm 0.305 a	0.420 \pm 0.104 b	0.569 \pm 0.086 b	0.624 \pm 0.046 b	0.469 \pm 0.079 b	0.245 \pm 0.080 c	0.578 \pm 0.031 a	0.427 \pm 0.078 b	2.873 \pm 0.025 a	1.327 \pm 0.073 c	0.327 \pm 0.071 b	
乙酸异戊酯	0.1 ^[26]	2	青草, 新鲜 Green, fresh	17.893 \pm 1.247 a	15.870 \pm 0.669 b	15.931 \pm 0.635 b	15.582 \pm 0.434 b	16.123 \pm 1.739 ab	15.304 \pm 0.198 b	15.443 \pm 0.567 b	18.430 \pm 1.321 a	17.950 \pm 0.161 b	20.685 \pm 1.286 ab	2.367 a	
乙醛	1 ^[24]	4, 8	花香, 玫瑰花香, 蜂蜜香 Floral, rose, honey	54.899 \pm 2.660 b	59.565 \pm 3.917 b	55.576 \pm 1.127 b	61.015 \pm 8.731 b	89.403 \pm 0.900 a	60.561 \pm 4.269 a	63.815 \pm 0.129 a	58.938 \pm 0.403 a	47.951 \pm 0.017 b	37.436 \pm 0.7274 a	5.466 \pm 0.433 b	
Acetaldehyde	0.1 ^[26]	1, 8	花香, 紫丁香, 烹苹果香 Floral, lilac, stewed apple	32.031 \pm 0.295 c	33.954 \pm 11.88 c	44.358 \pm 3.005 b	61.074 \pm 2.236 a	6.124 \pm 0.066 d	13.616 \pm 0.540 b	17.352 \pm 0.480 a	11.845 \pm 0.358 c	5.478 \pm 0.068 b	29.299 \pm 0.178 a	0.068 b	
癸醛	0.05 ^[25]	8	玫瑰花香, 紫罗兰 Floral, violet	0.09 ^[27]	0.114 a	0.484 \pm 0.248 a	4.575 \pm 0.868 a	4.593 \pm 0.399 a	4.563 \pm 0.399 a	4.563 \pm 0.165 a	4.812 \pm 0.283 b	5.279 \pm 0.238 a	5.279 \pm 0.238 a		
Decanal	0.02 ^[29]	6	燃油味 Kerosene	12.339 \pm 0.582 c	14.616 \pm 0.909 a	6.933 \pm 0.694 d	13.287 \pm 0.232 bc	13.458 \pm 0.102 b	11.909 \pm 0.038 a	11.904 \pm 0.108 a	5.055 \pm 0.381 b	5.729 \pm 0.552 b	8.589 \pm 0.078 a	3.718 \pm 0.608 c	
苯乙醛	30 ^[25]	8	玫瑰香, 天竺葵花香 Rose, geranium	1.524 \pm 0.005 d	1.877 \pm 0.020 a	1.892 \pm 0.027 a	1.839 \pm 0.012 b	1.577 \pm 0.007 c	1.983 \pm 0.046 a	1.693 \pm 0.013 b	1.699 \pm 0.032 b	1.460 \pm 0.019 b	1.793 \pm 0.157 a	1.320 \pm 0.126 c	
Phenylacetalddehyde	420 ^[27]	7	脂肪, 奶酪, 不新鲜的 Fatty, cheese, rancid	0.155 e	0.342 a	0.288 c	0.465 b	0.007 d	0.870 \pm 0.005 b	0.870 \pm 0.062 b	0.855 \pm 0.049 ab	0.734 \pm 0.052 b	0.664 \pm 0.052 b	0.715 \pm 0.064 a	
β-大马士酮	500 ^[25]	7	脂肪, 不新鲜的, 刺激, 奶酪 Fatty, rancid, harsh, cheese	1.225 \pm 0.094 d	2.341 \pm 0.181 a	1.929 \pm 0.034 b	2.215 \pm 0.097 a	1.434 \pm 0.940 d	2.215 \pm 0.870 \pm	1.386 \pm 0.085 a	1.489 \pm 0.049 ab	1.361 \pm 0.734 \pm	3.712 \pm 0.708 \pm	3.805 \pm 3.051 \pm	
β-damascenone	33.4 ^[27]	7	泡菜味、腐败味 Kimchi, rancid	1.033 d	55.893 \pm 0.869 a	47.492 \pm 3.519 a	4.608 \pm 0.784 b	5.094 \pm 3.268 \pm	3.268 \pm 0.982 a	4.033 \pm 0.240 b	3.712 \pm 0.038 b	3.712 \pm 0.157 a	3.712 \pm 0.126 c	0.076 b	
β-紫罗兰酮	14 000 ^[27]	8	玫瑰, 花香 Roses, flower	2.091 \pm 0.073 d	2.700 \pm 0.108 c	2.101 \pm 0.038 d	2.215 \pm 0.187 b	1.929 \pm 0.094 a	1.929 \pm 1.335 \pm	1.434 \pm 0.268 a	1.489 \pm 0.148 b	1.361 \pm 0.027 b	1.331 \pm 0.057 a	1.193 \pm 0.090 b	
辛酸	40 000 ^[25]	2, 6	芥酇味, 酱油味, 生青味 Fusel, alcohol, green	1.239 \pm 0.133 c	2.177 \pm 0.503 abc	1.597 \pm 0.393 bc	2.591 \pm 0.641 ab	3.019 \pm 0.819 a	3.156 \pm 0.464 a	3.291 \pm 0.488 a	3.255 \pm 0.359 a	3.18 \pm 0.307 a	3.18 \pm 0.307 b	1.002 \pm 0.088 a	
Octanoic acid	3-甲基-1,2-二氯苯	7	泡菜味、腐败味 Kimchi, rancid	0.127 e	1.979 \pm 0.132 d	3.110 \pm 0.256	3.773 \pm 0.493 bc	4.588 \pm 0.549 a	5.681 \pm 0.109 b	2.461 \pm 0.425 b	3.502 \pm 0.450 a	2.691 \pm 0.018 b	2.385 \pm 0.123 a	2.542 \pm 0.154 b	
异戊酸	1 ^[33]	5	生土豆味, 蒜味 Raw potato, garlic	0.009 ^[29]	2.233 \pm 0.054 a	0.162 \pm 0.003 a	0.171 \pm 0.044 a	0.160 \pm 0.010 b	0.280 \pm 0.003 a	0.280 \pm 0.006 c	0.160 \pm 0.006 c	0.280 \pm 0.009 a	0.184 \pm 0.009 a	0.184 \pm 0.006 b	
Isovaleric acid	500 ^[29]	2	青椒味 Peppery	0.002 ^[28]	2.233 \pm 0.054 a	0.162 \pm 0.003 a	0.171 \pm 0.044 a	0.160 \pm 0.010 b	0.280 \pm 0.003 a	0.280 \pm 0.006 c	0.160 \pm 0.006 c	0.280 \pm 0.009 a	0.184 \pm 0.009 a	0.184 \pm 0.006 b	
苯乙醇	14 000 ^[27]	8	椰子香 Coconut	32 ^[34]	10	椰子香 Coconut	2.233 \pm 0.054 a	0.162 \pm 0.003 a	0.171 \pm 0.044 a	0.160 \pm 0.010 b	0.280 \pm 0.003 a	0.160 \pm 0.006 c	0.280 \pm 0.009 a	0.184 \pm 0.009 a	0.184 \pm 0.006 b

348中居于前5位的香气物质是苯乙醛、异戊酸、己酸乙酯、癸醛和 β -大马士酮。3个营养系苯乙醛、苯乙醇OAV值差异不显著，‘梅鹿辄’181己酸乙酯、辛酸乙酯、香叶醇、己酸和辛酸显著高于‘梅鹿辄’343、348；‘梅鹿辄’343异戊酸和3-甲基硫醇显著高于‘梅鹿辄’181和348， β -大马士酮 $>181>348$ ($p \leq 0.05$)；‘梅鹿辄’348中乙酸异戊酯和癸醛显著高于‘梅鹿辄’181和343；‘梅鹿辄’343中乙酸乙酯、‘梅鹿辄’181中乳酸乙酯和‘梅鹿辄’348中TDN显著低于其他2个营养系。

‘品丽珠’327和c214OAV值居于第一位的是IBMP，且两者差异不显著，‘品丽珠’c214中居于第二至五位的分别是异戊酸、苯乙醛、乙酸异戊酯和己酸乙酯，而327中是辛酸乙酯、苯乙醛、己酸乙酯和癸醛；‘品丽珠’409居于第一至五位的是苯乙醛、 β -大马士酮、异戊酸、己酸乙酯和癸醛。‘品丽珠’c214己酸乙酯、乙酸乙酯和辛酸OAV值显著高于‘品丽珠’409和327，丁酸乙酯和乙酸异戊酯OAV值高于409和327($p \leq 0.05$)，苯乙醇和1-辛烯-3-醇显著低于‘品丽珠’409和327；‘品丽珠’409苯乙醛和 β -大马士酮显著高于‘品丽珠’c214和327；‘品丽珠’327

辛酸乙酯显著高于‘品丽珠’c214和409，癸醛显著高于‘品丽珠’c214。

如表6所示，葡萄酒挥发性香气特征主要有花香味、水果味、焦糖味、脂肪/奶油味、植物味、化学味。‘赤霞珠’霉土味、橡木味和香料味OAV值均小于5，5个营养系均以水果味特征最突出，OAV值最大，其中‘赤霞珠’338水果味OAV值 $>170>685、191、169$ ($p \leq 0.05$)，其次是花香OAV值 $>$ 焦糖味 $>$ 脂肪味/奶油味 $>$ 植物味 $>$ 化学味，‘赤霞珠’338花香味OAV值 $>170>169>685>191$ ($p \leq 0.05$)，‘赤霞珠’169焦糖味OAV值 $>191、170、338>685$ ($p \leq 0.05$)，‘赤霞珠’338、191脂肪味/奶油味OAV值 $>170、169>685$ 。‘梅鹿辄’348霉土味OAV值显著高于‘梅鹿辄’181和343，但均小于10；‘梅鹿辄’181花香味、水果和化学味OAV值 $>343>348$ ($p \leq 0.05$)且焦糖味显著高于后两者，而植物味显著低于‘梅鹿辄’348；‘梅鹿辄’343脂肪味/奶油味OAV值 $>181>348$ ；3个营养系均以花香味最突出，‘梅鹿辄’181和343中水果味OAV值 $>$ 焦糖味 $>$ 脂肪味/奶油味 $>$ 植物味 $>$ 化学味，而‘梅鹿辄’348中焦糖味 $>$ 水果味 $>$ 脂肪味/奶油味 $>$ 植物味 $>$ 化学味。‘品丽珠’葡萄酒，‘品丽珠’327花

表6 11个酿酒葡萄品种葡萄酒香气系列OAV值

Table 6 The flavor series of OAV values in wines of 11 wine grape lines

葡萄酒香气系列 Flavor series in wine	赤霞珠 Cabernet Sauvignon					梅鹿辄 Merlot			品丽珠 Cabernet Franc		
	685	191	170	338	169	181	343	348	c214	409	327
水果味 Fruity	165.556 \pm 5.363 c	175.176 \pm 10.465 c	246.903 \pm 12.105 b	283.534 \pm 3.4011 a	172.173 \pm 1.361 c	195.130 \pm 2.964 a	108.300 \pm 3.016 b	70.837 \pm 1.486 c	107.631 \pm 0.054 a	85.411 \pm 2.669 c	96.060 \pm 2.763 b
植物味 Plants	20.572 \pm 1.068 c	20.451 \pm 0.586 c	21.128 \pm 0.393 bc	22.903 \pm 0.185 ab	24.113 \pm 2.166 a	19.312 \pm 0.341 b	20.511 \pm 0.979 ab	22.083 \pm 1.320 a	80.196 \pm 0.659 b	21.942 \pm 1.474 c	85.669 \pm 1.317 a
干果味 Dryfruit	0.009 \pm 0.000 b	0.008 \pm 0.000 c	0.008 \pm 0.000 c	0.008 \pm 0.000 c	0.010 \pm 0.000 a	0.011 \pm 0.000 c	0.012 \pm 0.000 b	0.013 \pm 0.000 a	0.009 \pm 0.000 a	0.008 \pm 0.000 a	0.008 \pm 0.000 a
焦糖味 Caramel flavor	72.591 \pm 2.374 c	94.360 \pm 3.537 b	90.908 \pm 2.814 b	93.393 \pm 8.835 b	108.792 \pm 1.036 a	99.984 \pm 3.471 a	85.045 \pm 0.499 b	84.288 \pm 0.205 b	72.462 \pm 0.110 a	68.753 \pm 5.626 a	58.648 \pm 0.300 b
霉土味 Mildew earthy	1.239 \pm 0.133 c	2.177 \pm 0.503 abc	1.597 \pm 0.393 bc	2.591 \pm 0.641 ab	3.019 \pm 0.819 a	3.445 \pm 0.341 b	1.119 \pm 0.415 b	7.875 \pm 2.950 a	1.624 \pm 0.007 b	6.877 \pm 2.428 a	8.299 \pm 2.917 a
化学味 Chemical	14.122 \pm 0.438 d	18.283 \pm 0.535 b	11.569 \pm 0.126 e	16.751 \pm 0.295 c	19.536 \pm 0.674 a	16.264 \pm 0.352 a	14.531 \pm 0.503 b	8.911 \pm 0.174 c	10.096 \pm 1.110 b	12.113 \pm 0.029 a	6.150 \pm 0.702 c
脂肪味/奶油味 Fatty	43.817 \pm 1.325 c	68.598 \pm 1.321 a	58.732 \pm 0.019 b	67.561 \pm 4.450 a	60.807 \pm 0.814 b	56.525 \pm 2.771 b	68.412 \pm 0.126 a	50.342 \pm 2.115 c	45.718 \pm 0.267 a	36.640 \pm 0.294 b	28.706 \pm 7.873 b
花香味 Floral	160.233 \pm 2.154 d	150.387 \pm 1.904 e	218.305 \pm 9.170 b	229.172 \pm 4.643 a	171.754 \pm 0.882 c	206.598 \pm 4.869 a	148.815 \pm 0.963 b	84.648 \pm 0.178 c	58.754 \pm 0.143 c	89.703 \pm 7.233 b	106.201 \pm 1.113 a
烘烤味 Roasted	0.370 \pm 0.000 a	0.369 \pm 0.000 a	0.367 \pm 0.047 a	0.371 \pm 0.002 a	0.378 \pm 0.004 a	0.041 \pm 0.004 b	0.051 \pm 0.004 a	0.038 \pm 0.000 b	0.378 \pm 0.004 a	0.371 \pm 0.070 a	0.374 \pm 0.007 a
橡木味 Oak	2.915 \pm 0.088 a	0.228 \pm 0.001 c	0.064 \pm 0.002 d	0.090 \pm 0.007 d	2.039 \pm 0.011 b	0.463 \pm 0.060 a	0.284 \pm 0.015 c	0.379 \pm 0.005 b	0.228 \pm 0.011 b	0.379 \pm 0.011 a	0.245 \pm 0.003 b
香料味 Spicy	1.781 \pm 0.306 a	0.832 \pm 0.104 b	0.984 \pm 0.039 b	1.041 \pm 0.048 b	0.885 \pm 0.083 b	0.300 \pm 0.081 c	0.632 \pm 0.030 a	0.482 \pm 0.078 b	3.295 \pm 0.029 a	0.725 \pm 0.003 c	1.746 \pm 0.065 b

香味 OAV 值 $>409 > c214 (p \leq 0.05)$, 植物味 OAV $> c214 > 409 (p \leq 0.05)$; ‘品丽珠’c214 水果味 OAV 值 $> 327 > 409 (p \leq 0.05)$, 脂肪奶油味显著高于后两者; 3 个营养系中, ‘品丽珠’409 和 327 花香味、水果味居于前列, ‘品丽珠’409 焦糖味 $>$ 脂肪味/奶油味 $>$ 植物味, 而 ‘品丽珠’327 植物味 $>$ 焦糖味 $>$ 脂肪味/奶油味; 而 ‘品丽珠’c214 OAV 居于前列的是水果味、植物味, 其次是焦糖味 $>$ 花香味 $>$ 脂肪味/奶油味。

3 讨论

葡萄中的香气物质有游离态和糖苷结合态两种形式, 笔者主要测定了游离态挥发性香气成分。挥发性香气成分种类、含量、感觉阈值及相互作用决定葡萄和葡萄酒的风味, 同时也决定着所酿葡萄酒的风味和典型性, 在葡萄风味物质中有举足轻重的地位。本研究中, 11 个酿酒葡萄营养系果实和葡萄酒中挥发性香气成分共检测到 64~99 种、105~121 种, 显著高于已报道的研究中关于‘赤霞珠’^[17]、‘蛇龙珠’^[20]营养系果实或葡萄酒香气种类。这些香气成分为 7 类, 其中浓度最大的一类是中短链脂肪酸, 这与之前对于 5 个意大利引进酿酒葡萄品种果实香气的研究一致^[35], 该类化合物具有奶酪、刺激、脂肪味香气特点, 含量较高会破坏葡萄酒中香气^[36], 但是高含量与香气强度没有直接关系, 根据气味活性值理论, 只有浓度超过感觉阈值才能散发出气味^[37]; 11 个营养系果实中短链脂肪酸均未超过香气阈值, 而葡萄酒异戊酸 OAV 值较大, 其泡菜、腐败味^[27]对葡萄酒香气有一定负面影响, 特别是‘赤霞珠’191、338 和‘梅鹿辄’343 葡萄酒中异戊酸较高。乙醇酯是葡萄酒重要的香气物质, 呈果香、花香和甜香气^[35,38], ‘赤霞珠’191 果实中浓度最高, 且仅‘赤霞珠’191 中辛酸乙酯超过阈值, 其赋予果实香蕉、梨的水果香、花香^[27]; 11 个葡萄酒中乙醇酯浓度居香气浓度的第二或第三位, 其中己酸乙酯、辛酸乙酯、丁酸乙酯、乙酸乙酯、乙酸异戊酯和乳酸乙酯超过了阈值, 赋予葡萄酒果香、花香、奶油、脂肪味, 同一品种不同品系间有差异, ‘赤霞珠’5 个营养系中辛酸乙酯和乙酸异戊酯 OAV 值较高, 居于乙醇酯 OAV 值前两位, 而‘梅鹿辄’181、343 和‘品丽珠’327 乙醇酯中 OAV 值居前两位的是辛酸乙酯和己酸乙酯, ‘梅鹿辄’348 和‘品丽珠’c214、409 居前两位的是己酸乙酯和乙酸异戊酯。醇类物质是居于 11 个营养系果实香气

浓度的第二位, 居于葡萄酒香气浓度的第二或第三位, 但仅‘赤霞珠’4 个营养系中异丁醇超过阈值, 11 个营养系葡萄酒中苯乙醇、1-辛烯-3-醇和 3-甲硫基丙醇超过阈值, ‘赤霞珠’338、169 和‘品丽珠’3 个营养系葡萄酒中异丁醇超过阈值, 但是 OAV 值均小于 10, 表明醇类对于香气轮廓的影响较小。单萜和降异戊二烯赋予葡萄和葡萄酒特殊的品种香气^[39-40], 11 个营养系果实中 β -大马士酮、 β -紫罗兰酮和香叶醇均超过阈值, 不同品系间香叶醇 OAV 值差异较小, 但 β -大马士酮差异较大, ‘赤霞珠’5 个营养系 β -紫罗兰酮差异较大; 11 个营养系葡萄酒中 β -大马士酮和香叶醇均超过阈值, 不同营养系 β -大马士酮 OAV 值差异较大, β -紫罗兰酮仅 7 个品系超过阈值, 金合欢醇仅‘赤霞珠’170 超过阈值; 这些物质主要赋予果实和葡萄酒花香, 对于葡萄和葡萄酒花香特点有重要贡献。苯乙醛和癸醛是 11 个营养系果实和葡萄酒中均超过阈值的醛类物质, 分别赋予果实花香、甜香味和青草味。‘赤霞珠’170 果实中 Vitispirane B 超过阈值, ‘赤霞珠’170、338、169 和‘品丽珠’327 果实中 TDN 超过了阈值, 且‘赤霞珠’170 的 TDNOAV 值较大, 说明 TDN 是‘赤霞珠’170 果实化学味的主要贡献物质; 11 个营养系葡萄酒中 TDN 均超过阈值, 也是葡萄酒中化学味的主要贡献者。已有研究表明极端高温天气促进‘雷司令’果实和葡萄酒中产生 TDN^[41], 这也可能是本研究中葡萄果实和葡萄酒中 TDN OAV 值较大的原因。‘赤霞珠’191、170 和‘品丽珠’3 个营养系果实、‘品丽珠’c214、327 葡萄酒中 2-甲氧基-3-异丁基吡嗪 (IBMP) 超过阈值, 而 IBMP 是赋予‘赤霞珠’‘品丽珠’‘梅鹿辄’‘长相思’等葡萄或葡萄酒草本青椒味的主要化合物^[42-45]。挥发性香气成分能够引起不同的味觉和嗅觉。李媛媛等^[46]研究表明, 宁夏贺兰山东麓的‘赤霞珠’干红葡萄酒主要是花香和果香, 蒋宝等^[47]研究表明, 山西乡宁地区‘品丽珠’葡萄酒主要是果香和花香。产地、环境的不同可能造成同一品种在不同产地表现出不同的香气特征。本研究中 11 个营养系果实中, ‘赤霞珠’685、338、169 和‘梅鹿辄’3 个品系主要是花香、甜香, ‘赤霞珠’170 主要是化学味和花香, ‘赤霞珠’191 和‘品丽珠’3 个品系主要是花香和植物味。根据果实香气特征, ‘赤霞珠’685、169 是 11 个营养系中花香味、焦糖味、水果味 OAV 值最大的, 而‘赤霞珠’170 和‘品丽珠’中植物味 OAV 值较大, 且 170

化学味最大;‘品丽珠’327相比其他2个营养系花香味、水果香味最浓;‘梅鹿辄’3个营养系中348相比其他2个营养系花香、焦糖味、水果味最浓。11个品系葡萄酒中,‘赤霞珠’5个品系主要是水果味、花香,‘梅鹿辄’3个品系和‘品丽珠’409、327主要是花香、水果味,‘品丽珠’c214主要是水果味、植物味。根据葡萄酒香气特征,‘赤霞珠’338、170和‘梅鹿辄’181水果味、花香味OAV值较大,且具有一定脂肪奶油味、焦糖味;‘品丽珠’409与327、c214相比,植物味、水果味OAV值最小,花香味、焦糖味、脂肪奶油味居中。在酿酒时,可以根据这些香气特点进行筛选。

4 结 论

3个酿酒葡萄品种果实和葡萄酒中挥发性香气种类和浓度不同,同一品种不同营养系之间也有差异。果实、葡萄酒中共有的超过阈值的挥发性香气成分分别为5种、15种,其OAV值的差异导致果实、葡萄酒的香气特点和轮廓不同。根据气味活性值,‘赤霞珠’685、338、169和‘梅鹿辄’3个营养系果实主要是花香、甜香,‘赤霞珠’170主要是化学味和花香,‘赤霞珠’191和‘品丽珠’3个营养系主要是花香和植物味;‘品丽珠’c214葡萄酒主要是水果味、植物味,其余10个营养系葡萄酒主要是水果味、花香。根据果实香气特征,‘赤霞珠’685、169、‘品丽珠’327和‘梅鹿辄’348相对较好,根据葡萄酒香气特征‘赤霞珠’338、170、‘梅鹿辄’181和‘品丽珠’409较好。

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