Vol.36,No.18,2015

# 葡萄花色苷合成的影响因素研究进展

赵新节[1],韩爱芹[1],杨亲正[1,*],刘峻溪[2],赵　悦[1],李蕊蕊[2]
(1.齐鲁工业大学,山东省微生物工程重点实验室,山东济南 250353;
2.山东省农业科学院农产品研究所,山东济南 250100)

**摘　要**:花色苷是存在于葡萄果皮中的水溶性天然色素,属于类黄酮化合物。花色苷主要是由葡萄品种所决定的,但其生物合成还受到其他各种因素的调控,如气候(光照、温度和湿度)、土壤、植物激素、果实负载量等。本文对近年来影响葡萄花色苷合成的因素的研究进行综述,为改善葡萄果皮中花色苷的相关研究提供参考。

**关键词**:葡萄,花色苷,生物合成

# Research on factors influencing the biosynthesis of anthocyanin in grape fruit

**ZHAO Xin-jie[1],HAN Ai-qin[1],YANG Qin-zheng[1,*],LIU Jun-xi[2],ZHAO Yue[1],LI Rui-rui[2]**
(1.Shandong Key Laboratory of Microbial Engineering,Qilu University of Technology,Ji'nan 250353,China;
2.Institute of Agro-Food Science and Technology,Shandong Academy of Agricultural Sciences,Ji'nan 250100,China)

**Abstract**:As a big family of flavonoid,anthocyanin was one kind of natural water-soluble pigment. Besides grape cultivars,the biosynthesis of anthocyanin was also modulated by climate,soil,plant hormones,load. Recent advances in researches on factors influencing the biosynthesis of anthocyanin were reviewed with the purposes to provide reference for study on improving anthocyanin in grape skin.

**Key words**:grape;anthocyanin;biosynthesis
**中图分类号**:TS261.2　　**文献标识码**:A　　**文 章 编 号**:1002-0306(2015)18-0391-05
doi:10.13386/j.issn1002-0306.2015.18.071

花色苷作为类黄酮家族最大的一个分支,影响着葡萄酒的色泽、口感及营养价值,且直接决定红葡萄和新葡萄酒的颜色[1]。花色苷和单宁结合形成花色苷-单宁复合物,使得葡萄酒中的单宁软化,降低其苦涩味和粗糙感,使口感变得更加圆润。花色苷还能够清除自由基,其抗氧化性高于维生素C和维生素E[2]。除了抗氧化性,花色苷的抗突变、抗癌、抗高血糖活性均很高[3],赋予葡萄酒较高的营养价值。

花色苷存在于红葡萄最靠近表皮的3~4层细胞的液泡里[4]。从转色期开始,伴随着糖分的积累,葡萄果皮中的花色苷也开始迅速积累[5]。这一时期,花色苷主要以游离形式存在,随着葡萄的不断成熟,其含量也逐渐升高,并且单体之间开始聚合[6]。花色苷的生物合成路径可以分为两个阶段:第一阶段为苯丙烷类代谢途径,即由苯丙氨酸转化为4-香豆酰CoA;第二阶段为类黄酮途径,由4-香豆酰CoA转化为各种黄酮类化合物[7]。整个合成过程需要两类基因:编码酶的结构基因和编码转录因子的调节基因,图1简单展示了花色苷的合成路径及其过程中主要的结构基因,*myb*相关基因是花色苷合成中的调节基因,其调节结构基因的时空表达,进而影响花色苷合成的强度。葡萄果皮中花色苷的差异是内外部因素共同调控的结果,本文将从五个方面简单介绍内外因对葡萄花色苷的调控。

## 1　葡萄品种

葡萄花色苷主要是由基因型决定的,品种不同,其果皮中花色苷的含量和分布也有所不同。这主要是由于不同葡萄品种花色苷合成基因的表达模式不同造成的。欧亚种葡萄是世界上种植最广泛的酿酒葡萄,与其他葡萄品种的区别在于其不含有花色素双糖苷[8]。Fraige Karina[9]采用主成分分析的方法评估了品种之间的差异,证实了这一观点。欧亚种葡萄一般只含有花色素单糖苷:矢车菊素糖苷、飞燕草素糖苷、矮牵牛素糖苷、芍药素糖苷和锦葵素糖苷及其酰化衍生物,以锦葵素糖苷及其衍生物为主,但是欧亚种黑皮诺中仅含有非酰化的花色苷[10]。Arozarena Iñigo[8]在连续两年测定了不同品质葡萄园的添帕尼尤、歌海娜和赤霞珠果皮中花色苷的组成后,发现赤

---

**收稿日期**:2015-01-08

**作者简介**:赵新节(1962-),男,博士,教授,研究方向:葡萄与葡萄酒,E-mail:zhaoxinjie1177@163.com。

* **通讯作者**:杨亲正(1975-),男,博士,副教授,研究方向:生物纳米材料及葡萄酒化学成分分析,E-mail:yangqinzheng@sina.com。

**基金项目**:山东省现代农业产业技术体系水果创新团队项目(SDAIT-03-021-12)。

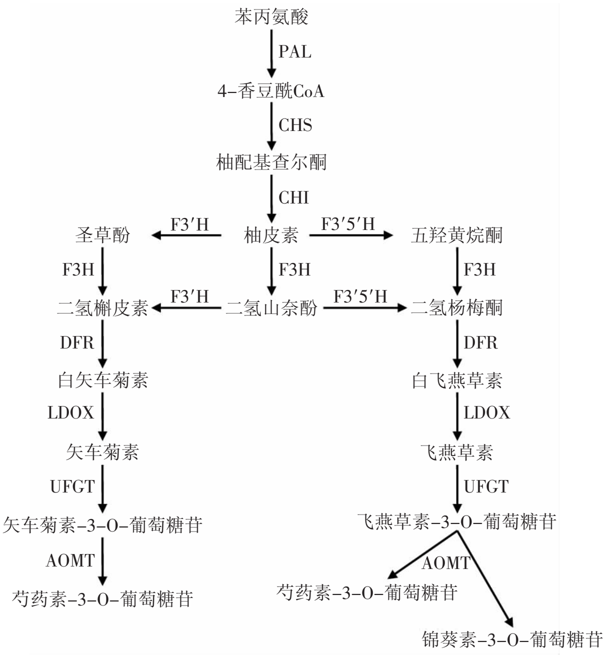

图1　花色苷的生物合成途径图

Fig.1　Simplified diagram of the anthocyanin biosynthetic pathway

注：PAL：苯丙氨酸解氨酶（phenylalanine ammonia-lyase）；CHS：查尔酮合成酶（chalcone synthase）；CHI：查尔酮异构酶（chalcone isomerase）；F3H：黄烷酮3-羟化酶（flavanone-3-hydroxylase）；F3′H：类黄酮3′-羟化酶（flavonoid 3′-hydroxylase）；F3′5′H：类黄酮3′,5′-羟化酶（flavonoid 3′5′-hydroxylase）；DFR：黄烷酮醇4-还原酶（dihydroflavonol-4-reductase）；LDOX：无色花色素双加氧酶（leucoanthocyanidin dioxygenase）；UFGT：UDP-类黄酮-3-O-葡萄糖基转移酶（UDP glucose:flavonoid-3-O-glucosyltransferase）；AOMT：O-甲基转移酶（anthocyanin O-methyltransferase）。

霞珠中乙酰化花色苷单体所占的比例明显高于添帕尼尤和歌海娜。Castellarin SD[11]在分别测定了九个葡萄品种中编码酶的基因及四个转录因子的表达水平后，认为品种间基因的特定表达模式的差异是造成花色苷不同的主要原因。

同一葡萄品种在不同风土条件下生长，其果皮中的花色苷也有差异。这是因为花色苷的生物合成还受外部因素包括气候、土壤、植物激素和负荷等的调控。随着对花色苷代谢途径研究的不断深入，研究影响花色苷生物合成的外部因素，进而通过采取合适的栽培措施来改善葡萄的品质，以酿造高品质葡萄酒成为当前研究的热点。

## 2　气候因素

### 2.1　光照

在强紫外照射下，高等植物会启动防卫机制，通过酚类物质的积累选择性地吸收紫外线就是一种有效的方式[12]。具体来说，由于转录因子控制花色苷生物合成中结构基因的时空表达[13]，而光照的刺激启动了光敏色素的信号传导途径，这些信号能进一步改变转录因子的表达水平，从而调控结构基因的表达[14]。另外，光照还可以通过影响光合作用中糖、苯丙氨酸等的合成来改变花色苷的积累[15]。铺反光膜、摘叶处理是最常用的增大葡萄受光面积的方法。在转色前期进行摘叶处理能增大葡萄的受光面积，进而影响叶片中花色苷的合成。Wu Ben Hong[16]研究了叶果比例对鲜食葡萄“京烟”花色苷的影响，证实适度减少留叶量有利于花色苷的积累，Jose TM[17]从分子的角度探究了光照对欧亚种赤霞珠花色苷合成的影响，发现转色期移动基生叶以增大果穗受光面积能够提高结构基因*Vvchs*2、*Vvldox*、*Vvomt*和*Vvufgt*的表达水平，但是摘除80%基生叶处理抑制了这四种结构基因的表达。故不同葡萄品种的最适叶果比例有待探究。

不仅光照强度会影响花色苷的生物合成，光质也会对其产生影响，可见光主要诱导原花色素的合成并影响其组成，而紫外线主要诱导黄酮醇的生物合成[18]。Kondo S[19]研究发现夜间蓝光或红光照射均能提高*Vvufgt*、*Vlmyba*1-2和*Vlmyba*2的表达量，其中UFGT催化不稳定的花色素形成各种花色苷，调节基因*myba*1-2和*myba*2则调节*ufgt*的时空表达。值得注意的是，夜间蓝光照射比红光照射更能促进糖分和花色苷的积累。

### 2.2　温度

温度是影响葡萄花色苷积累的重要因素[20]。一般认为，低温会促进花色苷的积累，而高温会抑制其合成[21]。Mori K[22]证实高温（35 ℃）会加速赤霞珠葡萄果皮中除锦葵色素糖苷以外的其他单体的降解，但是花色苷合成基因以及类黄酮-3-O-葡萄糖基转移酶UFGT的活性并没有被显著抑制，这与Takayoshi Yamane[23]的研究结果不同，其发现20 ℃下“Aki Queen”葡萄果皮花色苷合成中的7个结构基因以及调节基因*Vvmyba*1的表达量均高于30 ℃下的表达量。两者的差异可能是由于实验所用的葡萄品种不同，故其对温度的响应结果不同。

此外，温度与其他环境因素之间的协同作用也逐渐被重视，Koshita Yoshiko[24]认为低温和糖分积累协同作用促进了“Aki Queen”葡萄花色苷的合成，即当果实中糖分不足时，仅低温处理并不能促进花色苷的积累。Azuma Akifumi[25]研究了温度和光照对“先锋”葡萄（*V.* ×*labruscana*）的影响，发现同时具备低温和光照条件才能诱导结构基因*chs*2和*f3h*2的表达，另外，高温会显著降低*dfr*、*ufgt*和*omt*的表达水平，而三种编码转录因子的*myb*相关基因*Vlmyba*1-3，*Vlmyba*2和*Vlmyba*1-2对光照和温度的反应各不相同，其中温度显著影响*Vlmyba*1-3和*Vlmyba*2的表达水平，但对*Vlmyba*1-2的表达水平影响不大。

### 2.3　湿度

长期以来，限制水分供应是一种常用的提高葡萄多酚含量的农艺手段。水分胁迫提高葡萄果皮中花色苷的含量并不仅仅是通过限制果实的膨大，还通过提高类黄酮途径中结构基因的转录水平来促进花色苷的积累。Castellarin SD[26]证实水分胁迫能够显著提高欧亚种美乐葡萄花色苷合成路径中的结构基因特别是*ufgt*、*chs*2、*chs*3和*f3h*基因的转录水平。但

是，Bucchetti Barbara[27]在测定了四年干旱胁迫下美乐果皮中的花色苷后，认为减少水分是通过限制果实膨大来提高花色苷含量。赵权[28]进一步证实干旱胁迫可显著提高山葡萄果皮总花色苷的含量以及单体二甲花翠素-3-葡萄糖苷的含量，并使花色苷合成中的苯丙氨酸解氨酶PAL的活性有所提高。

## 3 土壤

土壤因素包含土壤类型、pH和营养元素等，也会影响葡萄花色苷的生物合成。葡萄偏爱的土壤类型为砂砾土和沙壤土，因为这两种土的通透性强，吸热快、比热大，使得昼夜温差大，能够促进糖分和花色苷的积累[29-30]。Koki Yokotsuka[31]通过添加石灰岩和牡蛎壳粉的方式来改善葡萄园的弱酸性土壤环境，发现这两种处理均能显著影响赤霞珠果皮中花色苷的组成。

适度的氮素胁迫有利于花色苷的生物合成，而氮含量较高则会抑制花色苷的合成，这与过量的氮元素加强了葡萄植株的营养生长，降低了糖分积累有关，更重要的是，氮素供应影响了花色苷合成中相关基因的表达水平。Soubeyrand Eric[32]从分子角度探究了氮元素对赤霞珠葡萄花色苷合成的影响，氮素胁迫下，一方面合成路径中结构基因*Vvdfr*、*Vvldox*和*Vvaomt*及调节基因*Vvmyba*1的转录水平大大提高，另一方面抑制花色苷合成的LBD蛋白质家族的转录因子*Vvlbd*39的表达水平降低。Cheng Guo[33]研究发现，当土壤中水分和有机质的含量较少时，赤霞珠的果粒重量减小但果皮重量增大，使果皮中花色苷浓度增加，另外，酰化花色苷的比例也有所增加，所酿造葡萄酒的颜色更加稳定。

## 4 植物激素

脱落酸（ABA）、乙烯等植物激素对花色苷的生物合成也发挥着重要的作用。脱落酸通过提高花色苷合成路径中基因的表达水平来促进花色苷的积累[34]，马立娜[35]和周莉[36]的研究结果证实了这一观点，并发现萘乙酸（NAA）处理会抑制花色苷的合成。另外，还有研究表明脱落酸可以促进单糖的积累[37]，而单糖正是花色素糖苷化必需的物质。乙烯则能够增强花色苷合成相关基因的转录，使转录时期前移，转录水平提高[38]。从植物生理角度分析，外源刺激物能够诱导植物积累特定的次级代谢产物来进行自身防御[39]。外源使用苯并噻二唑（BTH）和茉莉酸甲酯（MeJ）可诱导葡萄中类黄酮特别是花色苷的积累[40-41]。

## 5 负荷

葡萄叶片为葡萄植株的生长提供光合产物，葡萄果粒则是容纳光合产物的载体。改变葡萄植株负荷即选择合适的留果量，保证果实得到充足的糖分供应，从而提高果皮中花色苷的含量。Fanzone Martín[42]研究发现花后40 d疏穗50%促进了‘马贝克’葡萄果皮花色苷的生物合成，提高了果皮中总花色苷的含量。张家荣[43]对赤霞珠分别进行疏花、疏粒和疏穗三种处理，发现疏粒处理能够加大葡萄的松散度，改善果穗内部的光照条件，这有利于降低葡萄果粒间的温度，从而有助于花色苷的积累。M Gil[44]也证实了疏穗和疏粒处理均能提高西拉中花色苷的含量，与对照相比，两种处理下，五种非酰化花色苷单体的比例并无明显差异，但乙酰化和香豆酰化水平有差异。

## 6 结论与展望

花色苷作为葡萄和葡萄酒中主要的呈色物质，对葡萄酒的品质具有重要影响，因此，葡萄花色苷合成的分子机理及其调控是当前的研究热点。未来外部因素对花色苷合成和分解代谢路径中的酶活性、结构基因和调节基因表达的影响仍需进一步探明，另外，还可以利用蛋白质组学对花色苷合成机理进行研究，这将更有利于深化对葡萄花色苷代谢机理的认识，为改善葡萄果皮中的花色苷提供理论依据，从而有助于优质葡萄酒的研发。

## 参考文献

[1] Gómez Gallego MA, Gómez García-Carpintero E, Sánchez-Palomo E, et al. Study of phenolic composition and sensory properties of red grape varieties in danger of extinction from the Spanish region of Castilla-La Mancha[J]. European Food Research and Technology, 2011, 234(2): 295-303.

[2] Bagchi D, Garg A, Krohn RL, et al. Protective Effects of Grape Seed Proanthocyanidins and Selected Antioxidants against TPA-Induced Hepatic and Brain Lipid Peroxidation and DNA Fragmentation, and Peritoneal Macrophage Activation in Mice[J]. Gen Pharmac, 1998, 30(5): 771-776.

[3] 李阳，毕勇毅. 花色苷研究进展[J]. 公共卫生与预防医学，2009，20(1): 53-56.

[4] Núñez V, Monagas M, Gomez-Cordovés MC, et al. Vitis vinifera L.cv.Graciano grapes characterized by its anthocyanin profile[J]. Postharvest Biology and Technology, 2004, 31(1): 69-79.

[5] Coombe BG, McCarthy MG. Dynamics of grape berry growth and physiology of ripening[J]. Australian Journal of Grape and Wine Research, 2000, 6(2): 131-135.

[6] 杜文华，刘忠义. 葡萄酒中花色苷的研究进展[J]. 食品与机械，2011，27(4): 169-176.

[7] 孙欣，韩键，房经贵，等. 葡萄浆果着色分子机理的重要研究进展[J]. 植物生理学报，2012，48(4): 333-342.

[8] Arozarena I, Belén Ayestarán, María Jesús Cantalejo, et al. Anthocyanin composition of Tempranillo, Garnacha and Cabernet Sauvignon grapes from high-and low-quality vineyards over two years[J]. European Food Research and Technology, 2002, 214(4): 303-309.

[9] Fraige K, Pereira-Filho ER, Carrilho E. Fingerprinting of anthocyanins from grapes produced in Brazil using HPLC-DAD-MS and exploratory analysis by principal component analysis[J]. Food Chem, 2014, 145: 395-403.

[10] Ronald AF, Richard EK, A Dinsmoor Webb. Acetic-Acid-Acylated Anthocyanin Pigments in the Grape Skins of a Number of Varieties of Vitis Vinifera[J]. Anthocyanin Pigments Ingrape Skins, 1971, 22(3): 150-155.

[11] Castellarin SD, Gabriele DG. Transcriptional control of anthocyanin biosynthetic genes in extreme phenotypes for berry

pigmentation of naturally occurring grapevines[J]. BMC Plant Biol,2007,7(1):46.

[12] Alexei Solovchenko,Michaela Schmitz-Eiberger.Significance of skin flavonoids for UV-B-protection in apple fruits[J]. Journal of Experimental Botany,2003,54(389):1977-1984.

[13] Holton TA,Cornish EC. Genetics and Biochemistry of Anthocyanin Biosynthesis[J]. The Plant Cell,1995,7(7):1071-1083.

[14] 张龙,李卫华,姜淑梅,等. 花色素苷生物合成与分子调控研究进展[J]. 园艺学报,2008,35(6):909-916.

[15] 黄敬寒,温可睿,潘秋红,等. 环境条件和栽培技术对葡萄花色苷生物合成的影响(上)-环境条件对葡萄花色苷生物合成的影响[J]. 中外葡萄与葡萄酒,2011(9):71-76.

[16] Wu Ben Hong, Niu Ning, Li Ji-Hu, et al. Leaf:fruit Ratio Affects the Proteomic Profile of Grape Berry Skins[J]. J Amer Soc Hort Sci,2013,138(6):416-427.

[17] Jose TM, Loyola R, Vega A, et al. Post-veraison sunlight exposure induces MYB-mediated transcriptional regulation of anthocyanin and flavonol synthesis in berry skins of Vitis vinifera [J]. J Exp Bot,2009,60(3):853-67.

[18] Koyama K,Ikeda H,Poudel PR,et al. Light quality affects flavonoid biosynthesis in young berries of Cabernet Sauvignon grape[J]. Phytochemistry,2012,78:54-64.

[19] Kondo S, Tomiyama H, Rodyoung A, et al. Abscisic acid metabolism and anthocyanin synthesis in grape skin are affected by light emitting diode(LED) irradiation at night[J]. J Plant Physiol,2014,171(10):823-829.

[20] Takayoshi Yamane,Katsutoshi Shibayama.Effects of Changes in the Sensitivity to Temperature on Skin Coloration in Aki Queen Grape Berries[J]. J Japan Soc Hort Sci,2006,75(6):458-462.

[21] Cohen SD,Tarara JM,Kennedy JA. Assessing the impact of temperature on grape phenolic metabolism[J]. Anal Chim Acta, 2008,621(1):57-67.

[22] Mori K, Goto-Yamamoto Nami, Kitayama Masahiko, et al. Loss of anthocyanins in red-wine grape under high temperature [J]. J Exp Bot,2007,58(8):1935-1945.

[23] Takayoshi Yamane,Seok Tae Jeong,Nami Goto-Yamamoto, et al. Effects of Temperature on Anthocyanin Biosynthesis in Grape Berry Skins[J]. American journal of enology and viticulture, 2006,57(1):54-59.

[24] Koshita Yoshiko, Yamane Takayoshi, Yakushiji Hiroshi, et al. Regulation of skin color in ‘Aki Queen’ grapes:Interactive effects of temperature,girdling,and leaf shading treatments on coloration and total soluble solids[J]. Scientia Horticulturae,2011, 129(1):98-101.

[25] Azuma Akifumi, Yakushiji Hiroshi, Koshita Yoshiko, et al. Flavonoid biosynthesis-related genes in grape skin are differentially regulated by temperature and light conditions[J]. Planta,2012, 236(4):1067-1080.

[26] Castellarin SD, Pfeiffer Antonella, Sivilotti Paolo, et al. Transcriptional regulation of anthocyanin biosynthesis in ripening fruits of grapevine under seasonal water deficit[J]. Plant Cell Environ,2007,30(11):1381-1399.

[27] Bucchetti B,A Matthews Mark,Falginella Luigi,et al. Effect of water deficit on Merlot grape tannins and anthocyanins across four seasons[J]. Scientia Horticulturae,2011,128(3):297-305.

[28] 赵权,刘广娜,孔令瑶. 干旱胁迫对山葡萄花色苷合成及相关品质的影响[J]. 北方园艺,2012(24):44-46.

[29] 李记明,姜文广,于英,等. 土壤质地对酿酒葡萄和葡萄酒品质的影响[J]. 酿酒科技,2013(7):37-40.

[30] 李文超,孙盼,王振平. 不同土壤条件对酿酒葡萄生理及果实品质的影响[J]. 果树学报,2012,29(5):837-842.

[31] Koki Yokotsuka, Akitoshi Nagao, Kazuo Nakazawa, et al. Changes in anthocyanins in berry skins of Merlot and Cabernet Sauvignon grapes grown in two soils modified with limestone oroyster shell versus a native soil over two years[J]. Am J Enol Vitic,1999,50(1):1-12.

[32] Soubeyrand Eric, Basteau Cyril, Hilbert Ghislaine, et al. Nitrogen supply affects anthocyanin biosynthetic and regulatory genes in grapevine cv. Cabernet-Sauvignon berries[J]. Phytochemistry,2014,103:38-49.

[33] Cheng Guo, He YanNan, Yue TaiXin, et al. Effects of climatic conditions and soil properties on Cabernet Sauvignon berry growth and anthocyanin profiles[J]. Molecules,2014,19 (9):13683-13703.

[34] Ban T,Ishimmaru M,Kobayashi S,et al. Abscisic acid and 2,4-dichlorophenoxyacetic acid affect the expression of anthocyanin biosynthetic pathway genes in Kyoho grape berries [J]. Journal of Horticultural Science & Biotechnology,2003,78 (4):586-589.

[35] 马立娜,惠竹梅,霍珊珊,等. 油菜素内酯和脱落酸调控葡萄果实花色苷合成的研究[J]. 果树学报,2012,29(5):830-836.

[36] 周莉,王军. NAA和ABA处理对京优葡萄花色苷生物合成相关基因表达的影响[J]. 中国农业大学学报,2011,16(4):30-37.

[37] Pan Qiu Hong,Li Mei-Jun,Peng Chang-Cao,et al. Abscisic acid activates acid invertases in developing grape berry[J]. Physiologia Plantarum,2005,125(2):157-170.

[38] 于淼,赵权,王军. 乙烯利处理对葡萄花色苷合成相关基因表达的影响[J]. 植物研究,2012,32(2):183-190.

[39] 王宁宁,王淑芳,王勇,等. 外源刺激物对长春花冠瘿细胞生长和吲哚生物碱含量的影响[J]. 生物工程学报,1996(S1): 300-303.

[40] Ruiz-Garcia Yolanda, Romero-Cascales Inmaculada, Gil-Muñoz Rocio,et al. Improving grape phenolic content and wine chromatic characteristics through the use of two different elicitors:methyl jasmonate versus benzothiadiazole[J]. J Agric Food Chem,2012,60(5):1283-1290.

[41] Ruiz-Garcia Yolanda,Gil-Muñoz Rocio,López-Roca María Jose,et al. Increasing the phenolic compound content of grapes by preharvest application of abcisic acid and a combination of methyl jasmonate and benzothiadiazole[J]. J Agric Food Chem, 2013,61(16):3978-3983.

[42] Fanzone Martín, Zamora Fernando, Jofre Viviana, et al. Phenolic composition of Malbec grape skins and seeds from

(下转第399页)

of rice grain quality[M]. Philippines:International Rice Research Institute,1979:212-218.

[25] Desikachar H S R. Determination of the degree of polishing in rice I Some methods for comparison of the degree of milling [J]. Cereal Chemistry,1955,32:71-77.

[26] Bhattacharya K R, Sowbhagya G M. Technical note:An alkali degradation test and an alcoholic alkali bran-staining test for determining the approximate degree of milling of rice[J]. International Journal of Food Science & Technology,1976,11(3):309-312.

[27] 金增辉. 大米检验中的染色法[J]. 四川粮油科技,2003(4):54-61.

[28] Borasio L. Macrocolorimetric method for the evaluation of the degree of milling of rice[J]. Cereal Chemistry,1955,75(3):380-385.

[29] FAO. Degree of milling of rice:The standard method adopted by the food agency,government of Japan[S].

[30] Tani T, Chikubu S, Shikano T. A new M G method of staining for grain I Application to pressed barley and milled rice [J]. Shokuryo Kenkyusho Kenkyu Hokoku,1952(6):75-78.

[31] 中国国家标准化管理委员会. GB/T 18105-2000米类加工精度异色相差分染色检验法(IDS法)[S].

[32] 张浩,孟永成,周展明,等. 基于图像处理技术大米加工精度的检测研究[J]. 中国粮油学报,2006,21(4):135-137.

[33] Barber S, Barber C B. An approach to the objective measurement of the degree of milling[J]. Rice Process Engineering Centre,1976,2(2):1-8.

[34] 许俐,罗玉坤. 大米加工精度的图象识别方法[J]. 农业工程学报,1996,12(3):172-175.

[35] Chen H,Siebenmorgen T J. Effect of rice kernel thickness on degree of milling and associated optical measurements[J]. Cereal Chemistry,1997,74(6):821-825.

[36] Perdon A A, Siebenmorgen T J, Mauromoustakos A, et al. Degree of milling effects on rice pasting properties[J]. Cereal Chemistry,2001,78(2):205-209.

[37] Lam H S, Proctor A. Rapid methods for milled rice surface total lipid and free fatty acid determination[J]. Cereal Chemistry, 2001,78(4):498-499.

[38] Rohrer C A, Matsler A L, Siebenmorgen T J. Comparison of three extraction systems for determining surface lipid content of thickness-fractionated milled rice[J]. Cereal Chemistry,2004,81(4):544-548.

[39] Matsler A L, Siebenmorgen T J. Evaluation of operating conditions for surface lipid extraction from rice using a Soxtec system[J]. Cereal Chemistry,2005,82(3):282-286.

[40] Rao S N Raghavendra,Narayana M N,Desikachar H S R. Pattern of change in silica,ash,crude fibre,whiteness and bran pigmentation with progressive polish in rice varieties[J]. Journal of Food Science and Technology(Mysore),1972,9(2):51-53.

[41] Desikachar H S R. Determination of the degree of polishing in rice 2 determination of thiamine and phosphorus for processing control[J]. Cereal Chemistry,1955,32(1):78-80.

[42] Bhattacharya K R, Sowbhagya C M. A colorimetric bran pigment method for determining the degree of milling of rice[J]. Journal of the Science of Food and Agriculture,1972,23(2):161-169.

[43] Pomeranz Y,Stermer R A,Dikeman E. NMR-oil content as an index of degree of rice milling[J]. Cereal Chemistry,1975, 53:849-853.

[44] Liu W,Tao Y,Siebenmorgen T J,et al. Digital image analysis method for rapid measurement of rice degree of milling[J]. Cereal Chemistry,1998,75(3):380-385.

[45] Chen K J,Huang M. Prediction of milled rice grades using Fourier transform near-infrared spectroscopy and artificial neural networks[J]. Journal of Cereal Science,2010,52(2):221-226.

[46] Bergman C J,Goffman F D. A gas chromatography procedure for determining milled rice surface lipid content[J]. Cereal Chemistry,2007,84(2):202-205.

[47] Krishnan S,Ebenezer G A I,Dayanandan P. Histochemical localization of storage components in caryopsis of rice(*Oryza sativa* L.)[J]. Current Science,2001,80(4):567.

[48] Krishnan S, Dayanandan P. Structural and histochemical studies on grain-filling in the caryopsis of rice(*Oryza sativa* L.)[J]. Journal of Biosciences,2003,28(4):455-469.

[49] Patricia B M S,Jensen H H,Upton J. Rice consumption in the United States:recent evidence from food consumption surveys [J]. Journal of the American Dietetic Association,2009,109(10):1719-1727.

[50] Pedersen B, Eggum B O. The influence of milling on the nutritive value of flour from cereal grains 4 Rice[J]. Plant Foods for Human Nutrition,1983,33(4):267-278.

[51] Rahman M A, Miah M A K, Ahmed A. Status of rice processing technology in Bangladesh[J]. Agricultural Mechanization in Asia Africa and Latin America,1996,27:46-50.

[52] Sudha V,Spiegelman D,Hong B,et al. Consumer acceptance and preference study(CAPS) on brown and undermilled Indian rice varieties in Chennai,India[J]. Journal of the American College of Nutrition,2013,32(1):50-57.

[53] Shobana S, Malleshi N G, Sudha V, et al. Nutritional and sensory profile of two Indian rice varieties with different degrees of polishing[J]. International Journal of Food Sciences and Nutrition,2011,62(8):800-810.

◆

(上接第394页)

Valle de Uco(*Mendoza*,*Argentina*) during ripening.Effect of cluster thinning[J]. J Agric Food Chem,2011,59(11):6120-6136.

[43] 张家荣. 负载量及其调控方式对酿酒葡萄果实中花色苷的影响[D]. 济南:齐鲁工业大学,2013.

[44] Gil M, Esteruelas M, González E. Effect of Two Different Treatments for Reducing Grape Yield in *Vitis vinifera* cv. Syrah on Wine Composition and Quality:Berry Thinning versus Cluster Thinning[J]. Agric Food Chem,2013,61(20):4968-4978.