

‘徐香’与‘海沃德’猕猴桃冷藏期间组织结构与生理变化差异

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摘要: 以猕猴桃‘徐香’(较不耐贮藏)和‘海沃德’(耐贮藏)果实为试材, 研究其在 0 °C 贮藏期间生理及组织结构的变化差异, 从而探究其与耐贮性的关系。结果表明: 贮藏期间两品种果肉硬度均不断下将, ‘海沃德’果肉硬度降至 10 N 的时间为 150 d, 而‘徐香’仅为 95 d; ‘徐香’的呼吸高峰和乙烯释放高峰的出现分别较‘海沃德’早 20 d 和 10 d, 且峰值分别高出 16% 和 250%。贮藏期间‘徐香’果实的质量减少率也显著高于‘海沃德’。在整个贮藏期间, ‘海沃德’果实的淀粉、原果胶、纤维素含量均高于‘徐香’, 而淀粉酶(AM)、果胶代谢相关酶(多聚半乳糖醛酸酶 PG、果胶甲酯酶 PE、 β -半乳糖苷酶 β -Gal) 和纤维素酶(Cx)的活性高峰值均低于‘徐香’。‘海沃德’的表皮毛极显著细短于‘徐香’; 且角质层厚度及表皮细胞层数都大于‘徐香’; 贮藏期间果肉细胞的形变程度‘海沃德’小于‘徐香’; ‘海沃德’的细胞壁厚于‘徐香’, 且贮藏期间中胶层分裂缓慢, 线粒体较完整。总之, 耐贮性好的猕猴桃品种角质层和表皮细胞厚, 质量减少率较低, 呼吸速率和乙烯释放速率慢, 细胞壁酶活性低。

关键词: 猕猴桃; 耐贮性; 果胶酶; 超微结构; 组织结构

中图分类号: S 663.4

文献标志码: A

文章编号: 0513-353X (2020) 07-1289-12

Differences in Tissue Structure and Physiological Changes of ‘Xuxiang’ and ‘Hayward’ Kiwifruit Fruits During Cold Storage

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Abstract: Two kiwifruit cultivars ‘Xuxiang’ (shorter storage life) and ‘Hayward’ (long storage life), were used to study the changes in physiological and tissue structure during storage at 0 °C, so as to explore the internal mechanism of kiwifruit storage ability, and provide information for further selection of excellent cultivars with good storability. The results showed that the firmness of both kiwifruit cultivars decreased continuously, and the time of firmness dropping to 10 N during storage was 150 days and 95 days for ‘Hayward’ and ‘Xuxiang’, respectively. The peaks of respiratory rate and ethylene release rate on ‘Xuxiang’ appeared 20 days and 10 days earlier than that of ‘Hayward’, and the peak values were 16% and 250% higher than that of ‘Hayward’, respectively. The higher weight loss rate was observed on ‘Xuxiang’ as compared with ‘Hayward’. From the maturity stage to the following storage period, the

收稿日期: 2019-12-23; **修回日期:** 2020-03-22

基金项目: 国家“十三五”重点研发计划专项(2016YFD0400102); 陕西省科技统筹重大项目(2018TSCXL-NY-01-05)

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contents of starch, protopectin and cellulose of 'Hayward' were higher than that of 'Xuxiang', while the enzyme peak activities of amylase (AM), pectin (PG, PE, β -Gal) and cellulase (Cx) were lower than that of 'Xuxiang'. In terms of fruit tissue structure, the epidermal hair of 'Hayward' was significantly shorter than that of 'Xuxiang'. Moreover, the thickness of cuticle and the number of epidermal cells were larger than that of 'Xuxiang'. The degree of deformation in pulp cells of 'Hayward' during storage was less than that of 'Xuxiang'. Fruit ultrastructure showed that the cell wall of 'Hayward' was thicker than that of 'Xuxiang'; in addition, the division speed of cell wall and intercellular layer in 'Hayward' was slower as compared with 'Xuxiang'. Meanwhile, the mitochondria showed relative structural integrity in 'Hayward'. In conclusion, kiwifruit with good storage ability has thick cuticle and epidermal cells, low weight loss rate, slow respiration rate and ethylene release rate, and low cell wall enzyme activity.

Keywords: kiwifruit; storability; pectinase; ultrastructure; tissue structure

猕猴桃是典型的呼吸跃变型果实，其后熟过程会出现明显的呼吸跃变，生理代谢旺盛，淀粉快速降解，糖分增加，进而果肉变软、衰老、腐烂，不利于贮藏（黄文俊和钟彩虹，2017）。不同猕猴桃品种间果实耐贮性差异很大，培育品质优异且耐贮藏的品种是现代育种的主要目标（张培正等，1992；李东等，2015）。

猕猴桃‘海沃德’果实虽然糖酸比较低（Asiche et al., 2016），口味偏酸，但因其耐贮性好，在 0 °C 冷藏可高达 6 个月之久（Arpaia et al., 1987；Ritenour et al., 1999），而成为国际市场的主栽品种。‘徐香’是中国优良的猕猴桃品种之一，可溶性固形物含量较高，香味浓郁，酸甜可口，深受国人的喜爱（赵英杰等，2013），但其贮藏时间相对较短，且耐冷性较差（张浩，2014）。‘徐香’和‘海沃德’同属晚熟的美味系猕猴桃，且采收期基本一致，但两者的耐贮性差异很大（王西锐，2014）。

本试验中选用耐贮性差异较大的猕猴桃‘海沃德’和‘徐香’为试验材料，从果实采后生理及组织结构变化方面比较两者的内部差异，为选育品质优良耐贮藏的猕猴桃新品种提供参考。

1 材料与amp;方法

1.1 试验材料及其处理

供试猕猴桃‘徐香’和‘海沃德’均采自陕西省武功镇绿益隆公司同一猕猴桃基地，树龄、树形、树势及栽培管理一致且无膨大剂喷施。两品种在可溶性固形物达到一致时采收（采收时‘徐香’为 7%，‘海沃德’为 7.1%）。采收当天运回实验室，散去田间热。选择果形端正、大小均匀、果皮颜色均匀一致、无病虫害及机械损伤的果实，贮藏于 (0 ± 0.5) °C，RH 90%~95% 的冷库中。

每个品种随机挑选果实 450 个，设置 3 个生物学重复。入库当天测定初始值，之后每 10 d 取样 1 次进行相关指标的测定，并留样液氮速冻保存于 -80 °C 超低温冰箱用于后续其他指标的测定。直至果实硬度降至 10 N 停止取样，统计贮藏天数。并于入贮当天、呼吸跃变前后、贮藏末期 4 个时期取样，每个时期取 5 个果实，用于组织结构和亚细胞结构观察。入贮时，两品种每重复随机取样 15 个果实，用于呼吸速率和乙烯释放速率的测定，每个指标重复 3 次，同时两品种随机选取 50 个果实，用于统计失重率。

1.2 果实生理指标测定和果实结构观察

果肉硬度用 GY-4 型硬度计 (杭州绿博公司) 测定; 果实质量减少率参照 Khaliq 等 (2015) 的方法测定; 呼吸速率和乙烯释放速率的测定参照董晓庆等 (2009) 的方法, 分别使用 Tel-7001 型 CO₂ 分析仪 (美国 Telaire 公司) 和 Trace GC Ultra 型气相色谱仪 (美国 Thermo Scientific 公司); 淀粉酶活性的测定参照 Bonghi 等 (1996) 的方法, 淀粉含量的测定参照曹建康等 (2007) 的方法; 果胶含量的测定采用咪唑比色法, 纤维素含量的测定采取葱酮法, 果胶酶及纤维素酶活性测定采用分光光度法 (曹建康 等, 2007)。

石蜡切片的制作参照 Ban 等 (2016) 的方法, 于光学显微镜 (Olympus, U-TV0.63XC) 下观察、成像, 用 ImageJ 软件测量。

扫描电镜的观察参照 Konarska (2013) 的方法, 在 S-3400N 型扫描电子显微镜 (加速电压 5 ~ 15 kV) 下观察并数码拍照, 用 ImageJ 软件测量。

透射电镜的观察参照 He 等 (2018) 的方法, 于 JEM-1230 型透射电子显微镜 (JEOL, Tokyo, Japan) 下观察并数码拍照, 用 ImageJ 软件测量。

采用 Excel 2010 软件进行数据处理, 结果以平均值 ± 标准差表示。用 Sigma Plot 12.5 软件作图, 采用 ANOVA 单因素方差分析的 Duncan's Range Multiple 进行检验。

2 结果与分析

2.1 ‘徐香’和‘海沃德’猕猴桃果实贮藏期间相关生理指标的比较

2.1.1 硬度和质量减少率

果实硬度是反映果实耐贮性和衡量果实贮藏效果的重要指标。如图 1 所示, ‘徐香’和‘海沃德’采收当天的硬度分别为 118.8 和 144.9 N, 两者存在极显著差异。两个品种的果实硬度在整个贮藏期间均呈先快速下降后缓慢下降的变化趋势, 且‘海沃德’的硬度始终显著高于‘徐香’。当两者果实硬度下降至同一硬度 (10 N) 时, ‘海沃德’贮藏期达 150 d, 比‘徐香’ (95 d) 贮藏期长 55 d。

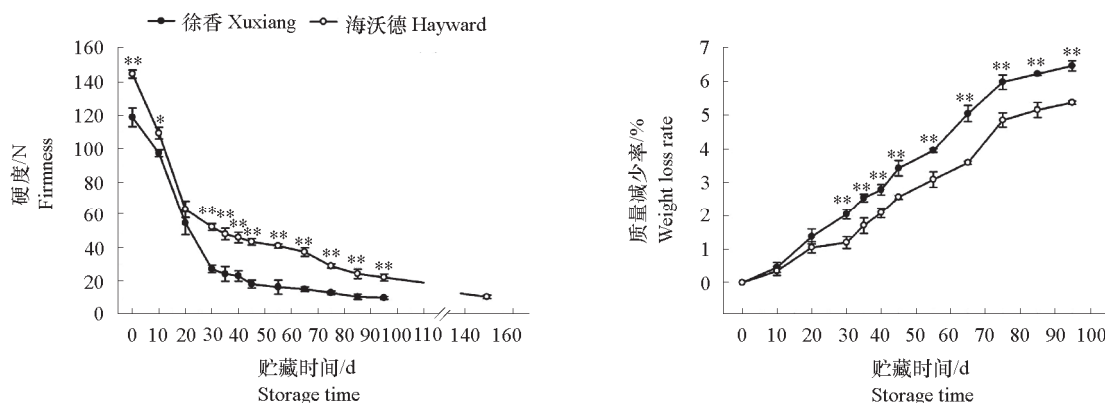


图 1 ‘徐香’和‘海沃德’猕猴桃果实贮藏期间果实硬度和质量减少率的变化

** 表示差异极显著 $P < 0.01$; * 表示差异显著 $P < 0.05$ 。下同。

Fig. 1 Changes of fruit firmness and weight loss rate during storage of ‘Xuxiang’ and ‘Hayward’ fruits

** means the difference is extremely significant at the 0.01 level; * means the difference is significant at the 0.05 level. The same below.

质量减少率是影响果实耐贮性的另一重要指标。随着贮藏时间的延长,两品种质量减少率均呈上升趋势,在贮藏中后期,‘海沃德’极显著低于‘徐香’。

2.1.2 呼吸速率和乙烯释放速率

如图 2 所示,两个品种果实贮藏期间的呼吸速率和乙烯释放速率均出现高峰。‘徐香’呼吸高峰出现在贮藏 10 d 时,峰值达 $8.43 \text{ mg} \cdot \text{kg}^{-1} \cdot \text{h}^{-1}$,‘海沃德’呼吸高峰出现在贮藏 30 d 时,峰值达 $7.27 \text{ mg} \cdot \text{kg}^{-1} \cdot \text{h}^{-1}$,与‘徐香’相比,推迟了呼吸高峰出现的时间且峰值也较低。‘徐香’乙烯释放高峰出现在 35 d 时,比‘海沃德’提前 5 d,且峰值是‘海沃德’的 3.5 倍。

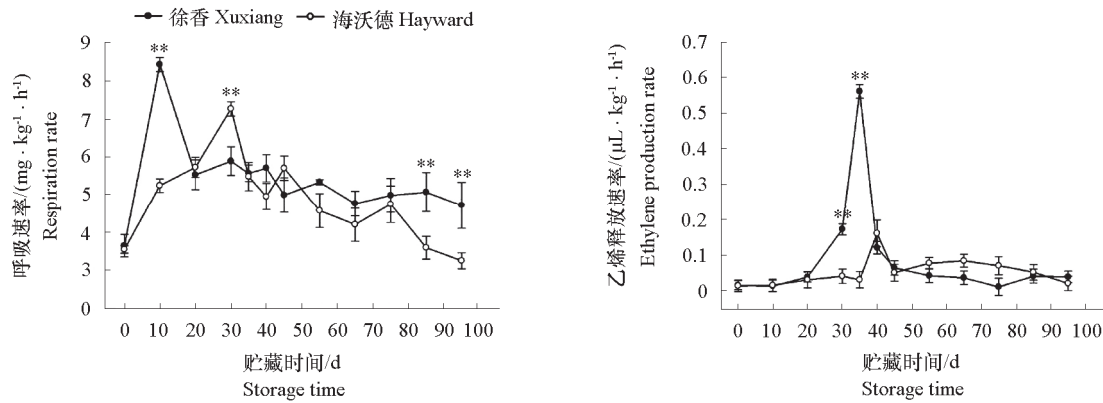


图 2 ‘徐香’和‘海沃德’猕猴桃果实贮藏期间呼吸速率和乙烯释放速率的变化

Fig. 2 Changes of respiration rate and ethylene release rate during storage of 'Xuxiang' and 'Hayward' fruits

2.1.3 淀粉含量和淀粉酶活性

如图 3 所示,采收当天,‘海沃德’淀粉含量极显著高于‘徐香’,在整个贮藏期间,淀粉含量均呈下降趋势,且‘海沃德’一直高于‘徐香’。此外,两个品种的淀粉酶活性呈先上升后下降的趋势,两者都在贮藏 40 d 时达到酶活性高峰,‘徐香’的峰值为 $5.83 \text{ mg} \cdot \text{g}^{-1} \cdot \text{min}^{-1}$,极显著高于‘海沃德’($4.79 \text{ mg} \cdot \text{g}^{-1} \cdot \text{min}^{-1}$)。

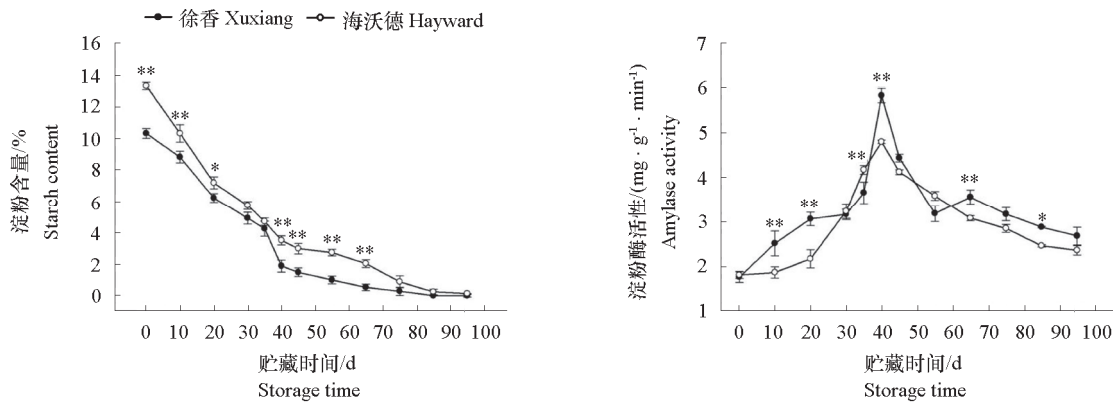


图 3 ‘徐香’和‘海沃德’猕猴桃果实贮藏期间淀粉含量和淀粉酶活性的变化

Fig. 3 Changes of starch content and amylase activity during storage of 'Xuxiang' and 'Hayward' fruits

2.1.4 纤维素含量和纤维素酶活性

纤维素是构成果肉细胞壁结构的重要物质, 与果实硬度密切相关。如图 4 所示, 在整个贮藏期, 两品种的纤维素含量均呈下降趋势, 且‘海沃德’始终极显著高于‘徐香’。两品种纤维素酶活性随着贮藏时间的延长均呈先升后降的趋势, 且都在 45 d 时出现高峰, ‘徐香’和‘海沃德’峰值分别为 3.09 和 2.53 $\text{mg} \cdot \text{h}^{-1} \cdot \text{g}^{-1}$, 前 45 d ‘徐香’极显著高于‘海沃德’。

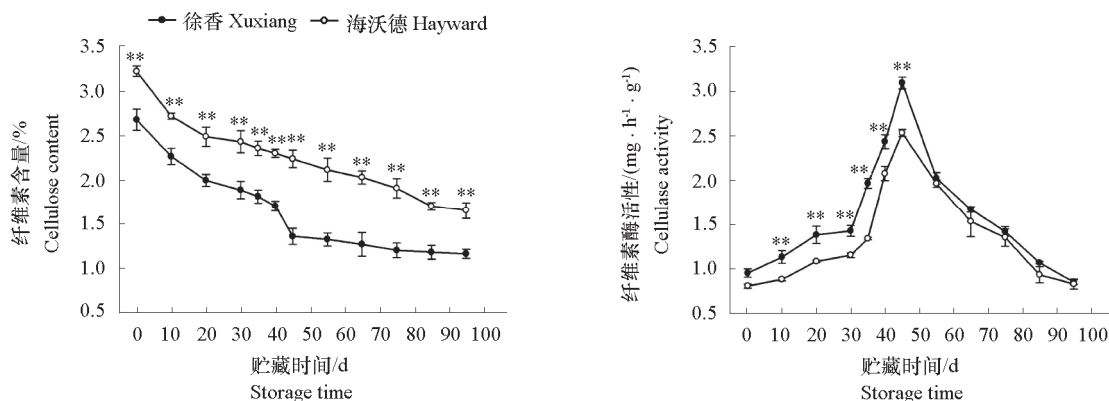


图 4 ‘徐香’和‘海沃德’猕猴桃果实贮藏期间纤维素含量和纤维素酶活性的变化

Fig. 4 Changes of cellulose content and cellulase activity during storage of ‘Xuxiang’ and ‘Hayward’ fruits

2.1.5 果胶物质

果胶是细胞壁初生壁和中胶层的重要组成成分, 果胶物质含量及成分的变化是影响果实硬度的关键因素之一。如图 5 所示, 在整个贮藏期间, ‘海沃德’原果胶 (Acid-soluble pectin, ASP) 含量均高于‘徐香’, 且在贮藏前 40 d 差异极显著。两品种水溶性果胶 (Water-soluble pectin, WSP) 均呈逐渐上升趋势, 且在整个贮藏期间‘徐香’极显著高于‘海沃德’。

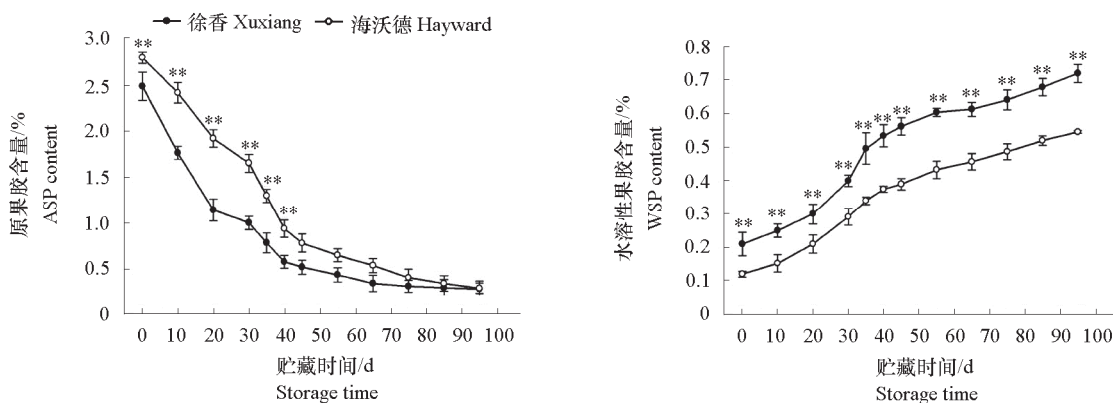


图 5 ‘徐香’和‘海沃德’猕猴桃果实贮藏期间原果胶和水溶性果胶的变化

Fig. 5 Changes of acid-soluble pectin (ASP) and water-soluble pectin (WSP) during storage of ‘Xuxiang’ and ‘Hayward’ fruits

2.1.6 细胞壁酶活性

果实软化过程中细胞壁降解与 PG、PE、 β -Gal 等酶活性密切相关。如图 6 所示，‘徐香’和‘海沃德’两品种果实的 PG 酶活性均呈先上升后下降趋势。‘徐香’在 45 d 达到高峰 ($2.6 \text{ mg} \cdot \text{h}^{-1} \cdot \text{g}^{-1}$)，‘海沃德’在 65 d 达到高峰 ($1.4 \text{ mg} \cdot \text{h}^{-1} \cdot \text{g}^{-1}$)，相比‘徐香’推迟 20 d 且峰值较低。两品种的 PE 酶活性也呈先升后降的趋势，在采收时二者均处于较低水平，差异不明显。但在整个贮藏期间，‘徐香’始终极显著高于‘海沃德’，前者在 30 d 达到高峰，后者在 40 d 达到高峰，同时前者峰值 ($1.83 \mu\text{mol} \cdot \text{min}^{-1} \cdot \text{g}^{-1}$) 是后者 ($0.78 \mu\text{mol} \cdot \text{min}^{-1} \cdot \text{g}^{-1}$) 的 2.3 倍。两品种的 β -Gal 酶活性呈波动上升趋势，且‘徐香’始终极显著高于‘海沃德’。

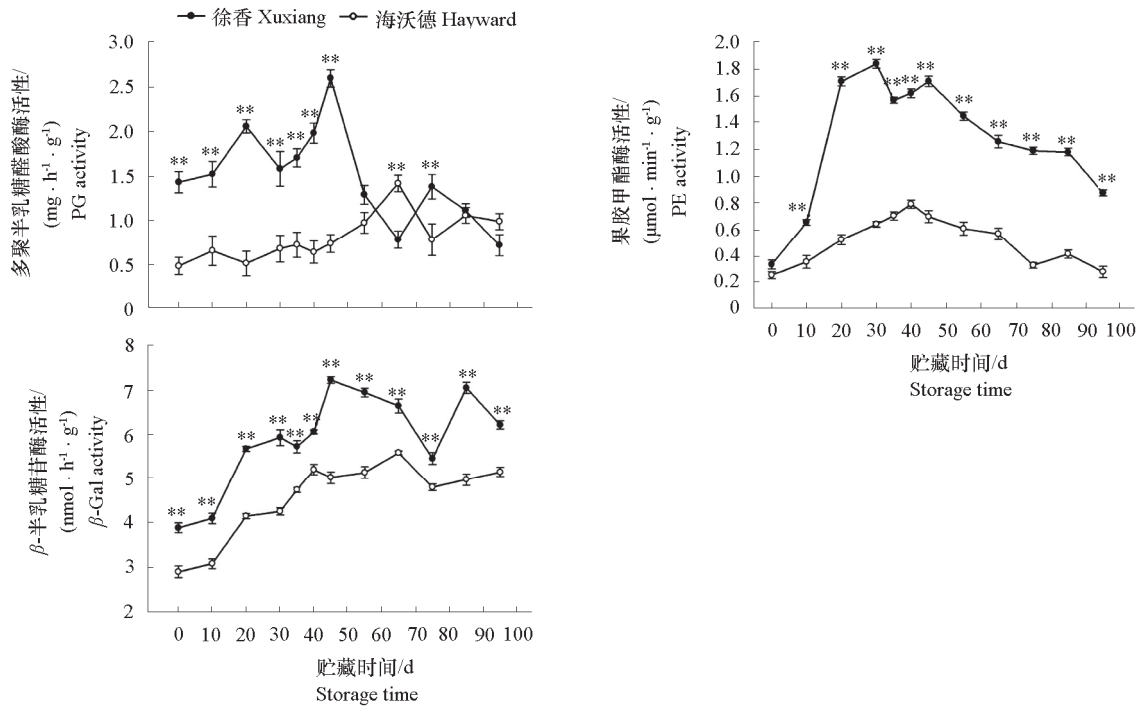


图 6 ‘徐香’和‘海沃德’猕猴桃果实贮藏期间 PG, PE 和 β -Gal 酶活性的变化

Fig. 6 Changes in PG, PE and β -Gal enzyme activities during storage of 'Xuxiang' and 'Hayward' fruits

2.2 ‘徐香’和‘猕猴桃’果实贮藏期间组织结构变化比较

2.2.1 表皮毛结构

通过扫描电镜观察和测量 (表 1) 得知，‘徐香’的表皮毛较‘海沃德’长而粗。‘徐香’的表皮毛长度为 2.42 mm，‘海沃德’为 1.67 mm；‘徐香’表皮毛直径为 52.16 μm ，‘海沃德’为 25.35 μm 。

表 1 ‘徐香’和‘海沃德’猕猴桃贮藏期间表皮结构及细胞壁厚度的差异

Table 1 Differences in epidermal structure and cell wall thickness of 'Xuxiang' and 'Hayward' during Storage

品种 Cultivar	表皮毛长度/mm Length of epidermal hair	表皮毛直径/ μm Diameter of epidermal hair	角质层厚度/ μm Thickness of cuticle	表皮细胞层数 The number of epidermis cell	细胞壁厚度/ μm Thickness of cell wall
徐香 Xuxiang	2.42 ± 0.06 A	52.16 ± 0.35 A	47.18 ± 0.75 B	3.00 ± 0.30 B	0.68 ± 0.08 B
海沃德 Hayward	1.67 ± 0.09 B	25.35 ± 0.69 B	81.35 ± 0.79 A	8.00 ± 0.35 A	1.39 ± 0.13 A

注：不同大写字母表示不同品种间差异显著。

Note: Different letters indicate significant difference.

如图 7 所示, ‘徐香’和‘海沃德’采收时两品种表皮毛覆盖度高且‘徐香’表皮毛更明显。到在贮藏末期 (90 d), ‘徐香’已皱缩, 失水严重, 而‘海沃德’仍较为饱满。

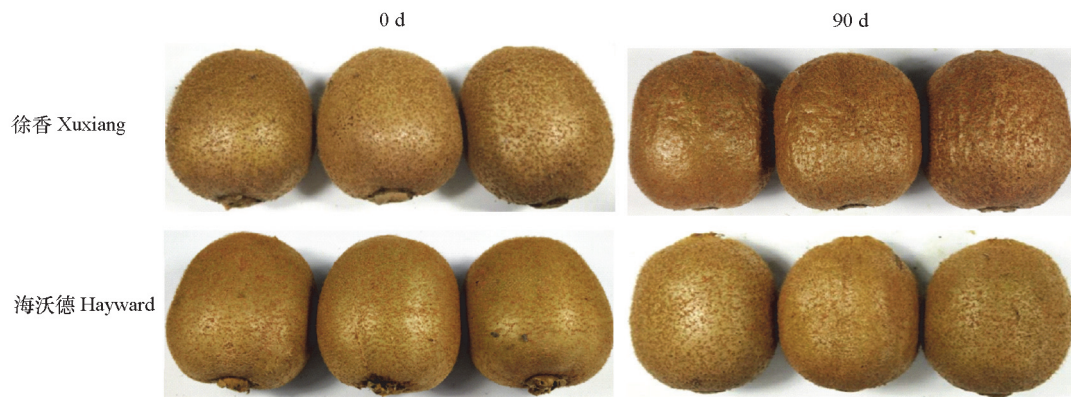


图 7 ‘徐香’和‘海沃德’猕猴桃果实表皮毛结构比较
Fig. 7 Comparison of the epidermal texture of the fruits of ‘Xuxiang’ and ‘Hayward’

2.2.2 细胞显微结构

两品种果实果皮均有一层质地均匀且连续的角质膜覆盖在表皮细胞的最外层上, 且内侧渗透到表皮细胞间隙中形成角质层。采收当天观察‘海沃德’的角质层比‘徐香’厚, 表皮细胞层数 (8 层) 约为‘徐香’ (3 层) 的 2.7 倍 (表 1), 细胞较粗短且排列紧密, 呈规则的长圆形, 而‘徐香’的表皮细胞较狭长且排列较为疏松 (图 8, 0 d)。

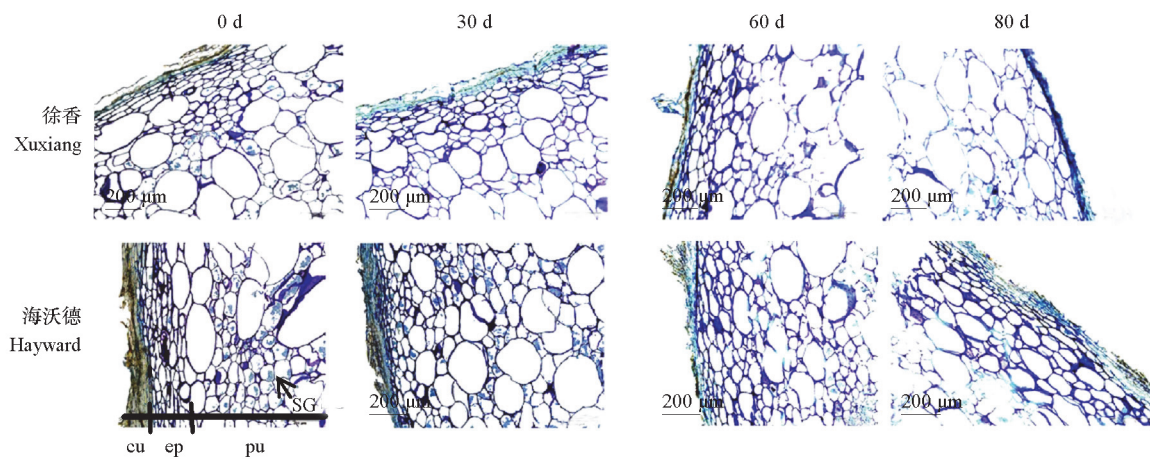


图 8 ‘徐香’和‘海沃德’猕猴桃果实贮藏期间细胞显微结构变化比较

cu: 角质层; ep: 表皮细胞; pu: 果肉细胞; SG: 淀粉粒。

Fig. 8 Comparison of cell microstructure changes during storage of ‘Xuxiang’ and ‘Hayward’ fruits

cu: Cuticle; ep: Epidermal cells; pu: Pulp cells; SG: Starch granule.

贮藏 30 d 时, ‘徐香’表皮细胞体积变大, 排列疏松, 果肉细胞体积也增大, 而‘海沃德’表皮细胞仍为长卵圆形、排列紧密, 同时果肉细胞也排列紧密 (图 8, 30 d); 贮藏至 60 d, ‘徐香’

果肉细胞失去饱满度、排列不规则；至 80 d 时，‘徐香’表皮细胞体积增大至近圆形，果肉细胞大量破裂，细胞壁染色程度低，形成许多小空腔，而‘海沃德’细胞变化较小，表皮细胞和果肉细胞排列仍紧密，果肉细胞仅有极少数破裂（图 8，60 d、80 d）。

2.2.3 细胞壁超微结构

对这两个品种的果实薄壁组织进行亚细胞结构观察：采收当天，果肉细胞的细胞质与其内含物紧贴细胞壁，细胞壁整齐，结构致密，呈明一暗一明分区结构；中胶层为一薄的高电子密度暗层，均匀且连续；内含有大量结构完整、质膜清晰的细胞器（图 9，0 d）；‘海沃德’细胞壁 1.39 μm ，极显著厚于‘徐香’的 0.68 μm （表 1）。贮藏 40 d 时，‘徐香’中胶层已裂解，细胞之间相互分离，形成大的细胞间隙，而‘海沃德’胞间层仍可见，细胞壁结构仍较完整（图 9，40 d）。贮藏末期（80 d），‘徐香’细胞壁结构已严重变形，质壁分离，形成絮状空隙，微纤丝散落，而‘海沃德’胞间层稍有溶解，微纤丝较为松散，结构较为完整（图 9，80 d）。

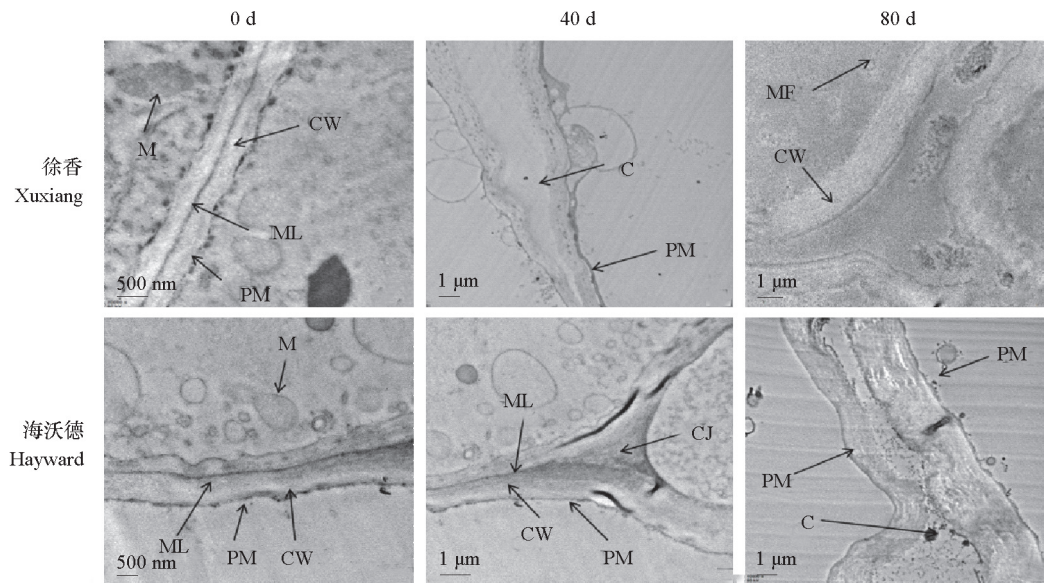


图 9 ‘徐香’和‘海沃德’猕猴桃果实贮藏期间果肉细胞壁超微结构变化比较

CW: 细胞壁; ML: 中胶层; M: 线粒体; PM: 质膜; CJ: 三细胞连接处; MF: 微纤丝; C: 裂痕。

Fig. 9 Comparison of ultrastructural changes in pulp cells during storage of 'Xuxiang' and 'Hayward' fruits

CW: Cell wall; ML: Medium adhesive layer; M: Mitochondria; PM: Plasma membrane;

CJ: Three-cell junction; MF: Microfibril; C: Rift.

2.2.4 线粒体超微结构

对两品种果实薄壁组织进行透射电子显微镜观察发现，在采收当天，两品种线粒体结构完整，呈球状或杆状，基质充满整个线粒体（图 10，0 d）；贮藏 40 d 时，‘徐香’线粒体出现肿胀变大，内部结构模糊不清，有一部分线粒体已空泡化，而此时‘海沃德’线粒体结构虽稍有膨大，内部结构模糊，但无空泡化的线粒体出现（图 10，40 d）；至贮藏末期（80 d），‘徐香’线粒体几乎全部空泡化，破裂崩解，而‘海沃德’线粒体结构只有少数出现空泡化，结构相比‘徐香’较为完整（图 10，80 d）。

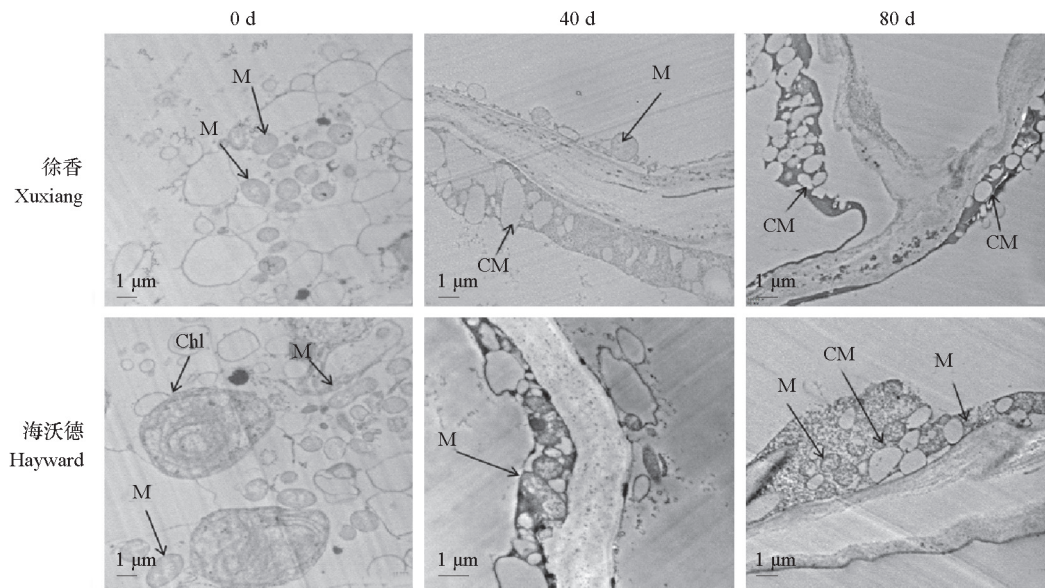


图 10 ‘徐香’和‘海沃德’猕猴桃果实贮藏期间线粒体超微结构变化比较

M: 线粒体; Chl: 叶绿体; CM: 空泡化线粒体。

Fig. 10 Comparison of mitochondrial ultrastructural changes during storage of ‘Xuxiang’ and ‘Hayward’ fruits

M: Mitochondria; Chl: Chloroplast; CM: Vacuolated mitochondria.

3 讨论

3.1 果实结构与耐贮性的关系

果实耐贮性与果实自身的结构密切相关, 果皮角质层和表皮细胞的厚度都会影响果实水分的散失, 导致果实质量减少, 硬度下降 (Maguire et al., 1999; Veraverbeke et al., 2003)。角质层具有耐酸碱、耐氧化和不易透水、透气的特性 (李宏建 等, 2013)。果实贮藏期间, 角质层有延缓气体交流, 抑制呼吸, 减少水分散失的作用 (林建城, 2007)。本研究中, 耐贮藏的猕猴桃‘海沃德’角质层较厚, 且深入到表皮细胞之间, 表皮细胞层数较多, 果肉细胞短小, 形状规则, 排列紧密; 而较不耐贮藏的‘徐香’果肉细胞狭长, 大小不均匀, 排列较为松散, 且随着贮藏时间的延长, 果肉细胞变化幅度比较大。此外, ‘徐香’表皮毛比‘海沃德’的粗且长, 贮藏末期前者果实表面已皱缩, 而后者相对饱满, 这可能也与表皮毛的面积有关, 表皮毛面积越大, 果实表面的蒸腾面积越大, 果实失水越严重, 进而引起果实生理代谢紊乱, 呼吸作用加强, 相关物质降解加快, 导致果实硬度下降, 耐贮性变差。

3.2 呼吸速率和乙烯释放速率与果实耐贮性的关系

呼吸作用和乙烯释放是果实采收后新陈代谢的主导因素, 在果实后熟与软化过程中起主要的调控作用 (吴彬彬 等, 2008; Gwanpua et al., 2014; Ireland et al., 2014)。刘超超等 (2011) 报道, 3 个苹果品种的呼吸和乙烯释放高峰后出现细胞壁降解酶活性高峰, 引起果实软化。本研究中耐贮

的猕猴桃‘海沃德’的呼吸和乙烯释放高峰比不耐贮的‘徐香’晚且峰值低。这与 Gwanpua 等 (2013) 报道的采收后快速软化的品种乙烯释放量相对较高, 而软化相对缓慢的品种相对较低的结果一致。

3.3 淀粉含量与果实耐贮性的关系

淀粉有维持细胞膨压的作用, 对细胞起支撑作用 (张永平等, 2008; Yang et al., 2013)。随着采收后呼吸速率和乙烯释放量的增加, 淀粉酶活性升高, 促进淀粉迅速水解, 引起细胞膨压降低, 果实软化。在本研究中, ‘海沃德’的淀粉含量一直高于‘徐香’, 淀粉酶活性也较低, 这是在整個贮藏期间前者硬度始终高于后者的原因之一。同时, 对两品种组织结构观察也表明了‘海沃德’刚采收时, 果肉细胞中含有较多淀粉颗粒, 随着贮藏时间延长, 淀粉颗粒不断减少, 但减少幅度比‘徐香’小。

3.4 细胞壁多糖降解与果实耐贮性的关系

果肉细胞壁的完整性决定了果实硬度。果胶和纤维素是构成果肉细胞壁的重要物质, 果胶是果实细胞壁中胶层的主要组分 (Seymour et al., 1990)。果实硬度与果胶降解、果胶酶活性的变化密切相关 (Ketsa & Daengkanit, 1999; 罗静等, 2018)。本研究结果显示, 采收初期耐贮藏的猕猴桃‘海沃德’的原果胶和纤维素含量都比不耐贮藏的‘徐香’高, 前者细胞壁厚度为后者的 2 倍; 随着果实的后熟, ‘海沃德’的 PG、PE、 β -Gal、Cx 活性高峰均比‘徐香’出现晚且峰值低, 水溶性果胶的生成和原果胶、纤维素的分解比‘徐香’缓慢; 在贮藏中期, ‘徐香’中胶层基本溶解, 微纤丝散落, 细胞壁层变薄, 果肉硬度迅速下降, 而‘海沃德’中胶层仍可见, 结构较完整。

3.5 线粒体结构与耐贮性的关系

线粒体代谢活性与果实的成熟软化有着必然的联系 (阚娟等, 2015)。细胞衰老时线粒体功能会发生退行性改变, 线粒体功能的正常有赖于其结构的稳定 (Kataoka et al., 2005; Collman et al., 2008)。本试验中, 猕猴桃果实伴随着硬度的下降线粒体结构均有退化。但是至贮藏末期, 不耐贮藏的‘徐香’线粒体膜裂解较为严重, 均已空泡化, 而耐贮藏的‘海沃德’结构相对完整, 这说明了相对完整的线粒体结构可能是其维持较高硬度的原因之一。

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