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Postharvest osmotic dehydration of pedicels of sweet cherry fruit

Moritz Knoche*, Thomas O. Athoo, Andreas Winkler, Martin Brüggenwirth

Institute for Horticultural Production Systems, Leibniz-Universität Hannover, Herrenhäuser Straße 2, 30419 Hannover, Germany

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ABSTRACT

The appearance of the pedicels is a good indicator of postharvest freshness of sweet cherry fruit (*Prunus avium* L.). Shrivelled pedicels are thought to result from water loss due to pedicel transpiration after extended periods of storage or after storage under inferior (drying) conditions. This study establishes that osmotic dehydration can also be a factor in pedicel deterioration during storage. A time course study revealed that the water content of a pedicel attached to its fruit and incubated at 100% relative humidity (RH) decreased within 24 h and remained approximately constant thereafter. In contrast, the water content of a detached pedicel, increased slightly and continuously over nine days. Similarly, pedicel diameter decreased when a pedicel remained attached to its fruit but did not decrease when it was detached. Pedicels that remained attached to their fruit yellowed more rapidly than the ones that had been detached. Pedicel dehydration was not related to pedicel transpiration, as this was effectively zero at 100% RH. The decrease in water content of attached pedicels was accompanied by a corresponding increase in osmolarity. However, the osmolarity of detached pedicels decreased slightly. Potometry revealed a continuous flow of water through the pedicel into the fruit even though the fruit was held under non-transpiring conditions (100% RH). When a fruit and pedicel was mounted on a pressure probe (100% RH), a slight negative pressure developed that gradually approached an equilibrium value of -30.3 ± 2.0 kPa. Our results demonstrate that osmotic dehydration accounts for pedicel shrivelling recorded at 100% RH.

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1. Introduction

The pedicel of a sweet cherry fruit is an indicator of its postharvest freshness. To the consumer, green and turgid pedicels imply fresh fruit, whereas yellowed or brown and shrivelled pedicels imply aging fruit. To the retailer, they indicate unreasonable delays between harvest and marketing and/or poor postharvest handling and storage conditions. The commercial result of pedicel browning and shrivelling is a reduction in retail value for what is normally a very high-value product. Browning and shrivelling are caused by dehydration of the pedicel and, to this point, pedicel transpiration in a non-saturated atmosphere has been assumed to be the sole mechanism of pedicel dehydration (Linke et al., 2010; Smith and Whiting, 2011). However, there is a second possible mechanism for pedicel dehydration. Recent research has established that turgor in sweet cherry fruit is low at maturity, despite their high concentrations of carbohydrates (Knoche et al., 2014; Schumann et al., 2014). In a post-veraison grape berry, which is morphologically similar and also has low turgor (Matthews and Shackel, 2005), the essential absence of turgor has been accounted for by the presence of osmolytes in the apoplast (Lang and Düring, 1991; Wada et al., 2008, 2009). Essentially, the apoplastic osmolytes bring into balance the osmotic potentials on either side of the plasma membrane, thereby reducing to almost nothing the difference in osmotic potentials between apoplast and symplast. At water potential equilibrium, it is this difference that determines cell turgor. The same explanation may also apply with sweet cherry, because: (1) the pedicel surface of sweet cherry is more permeable to water than the fruit surface (Athoo et al., 2015), and (2) the fruit's apoplast and the pedicel's xylem remain hydraulically connected even if an abscission layer is formed (Wittenbach and Bukovac, 1972), pedicel transpiration generates a driving force for water movement via the xylem out of the fruit into the pedicel when the fruit is held in a non-saturated atmosphere (Athoo et al., 2015). Accordingly, in a saturated atmosphere the negative water potential in the fruit's apoplast resulting in part from the apoplastic osmolytes would reverse this driving force causing dehydration of the fruit's pedicel. In addition, if freely diffusible, the osmolytes in the apoplast will diffuse into the pedicel thereby tending to cancel out any water potential and chemical concentration differences between pedicel and fruit. This scenario would

* Corresponding author. Fax: +49 511 762 5852.
E-mail address: moritz.knoche@obst.uni-hannover.de (M. Knoche).

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account for pedicel dehydration by osmotic water loss even at 100% RH as would typically be the case in (modified atmosphere) packaged sweet cherries. To our knowledge, this hypothesis has not previously been either postulated or investigated.

The objectives of this study were: (1) to determine whether pedicel dehydration occurred when a fruit was held at 100% RH and, if so, (2) to identify the mechanisms and consequences of this dehydration.

2. Materials and methods

2.1. Plant materials

Mature, greenhouse- and field-grown sweet cherry fruit (*Prunus avium* L.) of the cvs 'Frühe Rote Mecklenburger', 'Sam' and 'Regina' were sampled from an experimental orchard of the Horticultural Research Station of Leibniz University in Ruthe (N52°14′, E9°49′). All trees were grafted on Gisela 5 rootstocks (*Prunus cerasus* L. × *Prunus canescens* Bois). Fruit were sampled in the mornings, brought to the laboratory and processed on the same day. Fruits were individually selected for color uniformity and freedom from visible defects. Pedicels were detached by excising a length from the receptacle end of longer pedicels. Unless otherwise specified, pedicel length was standardized to 20 mm.

2.2. Experiments

2.2.1. Change in water content, pedicel diameter and pedicel color

The time course of change in water content, pedicel diameter and color was established in mature 'Regina' for pedicels remaining attached to their fruit and also for detached pedicels. Fruits with the pedicel attached and detached pedicels were incubated under low-light conditions in polyethylene boxes at 100% RH. Pedicels were harvested after 0, 24, 48, 72, 96, 144, and 216 h and their fresh mass determined by weighing (BP211D; Sartorius, Göttingen, Germany). Calibrated digital images of pedicels were taken (MZ6; Leica Mikrosysteme, Bensheim, Germany; DP71; Olympus, Hamburg, Germany). Thereafter, pedicels were dried to constant weight in an oven at 70 °C for a minimum of 24 h, their dry weights were determined and their water contents and dry matter contents calculated. Pedicel diameter (cell^{P}; Olympus, Hamburg, Germany) and pedicel color (Paint.NET, v3.5.10; freeware available at http://www.getpaint.net) were quantified by image analysis. To describe the change in pedicel color, the hue angle was used (McGuire, 1992). The number of individual pedicel replicates was 15.

2.2.2. Effect of temperature on diameter and color of pedicels remaining attached to the fruit and of detached pedicels

The effect of temperature on shrivelling and yellowing of attached or detached pedicels (at full length) was studied in 'Regina'. Fruit with pedicels attached and detached pedicels were incubated at 100% RH at either 2 °C or 22 °C. Pedicel diameter and pedicel color were measured after 0, 2, 7, 14, 28, and 48 d at 2 °C and at 0, 2, 7, and 14 d at 22 °C. Color was quantified in the CIE 1976 (L*, a*, b*) scale as defined by the Commission Internationale de l'É-clariage (McGuire, 1992) at five random positions per pedicel using a spectrophotometer (CM-2600d; Konica Minolta, Osaka, Japan). Hue angles were calculated as described by McGuire (1992). The number of replications that remained for final analysis ranged from five to ten.

2.2.3. Time course of change in osmolarity of pedicels that remained attached to the fruit and of detached pedicels

The time course of change in osmolarity was investigated in 'Regina' sweet cherries using pedicels that remained attached to the fruit and using detached pedicels. Fruit with pedicels and detached pedicels were incubated at 100% RH at 22 °C for 0, 4, 6, 24, 48, or 72 h. Thereafter, pedicels were cut into short sections and transferred to the sampling plate of the water vapor pressure osmometer (VAPRO® 5520 and 5560; Wescor, Logan, UT). Their osmolarity was read after 30 min of incubation. Preliminary experiments established that (1) the water vapor pressure of the atmosphere in the sampling chamber equilibrated with the pedicel sample within 30 min and (2) there was little difference in osmolarity between pedicels having their turgor destroyed by freezing and subsequent thawing (2.32 ± 0.05 MPa) and fresh pedicels (2.27 ± 0.15 MPa). Thus, cell turgor and tissue pressure of the pedicels must have been low (0.05 ± 0.09 MPa) and the readings obtained, satisfactorily estimated the osmolarity of the tissues. Following osmometry, pedicels were dried at 70 °C as described above, weighed and the water content calculated. To relate pedicel osmolarity to fruit osmolarity, the expressed juice of fruit from the same batch was sampled and its osmolarity determined. The minimum number of replicates was four, and one replicate comprised three pedicels.

2.2.4. Potometry

Osmotic flow of water from a pedicel into a fruit was investigated in 'Frühe Rote Mecklenburger' sweet cherries using potometry. A fruit was detached from the tree by cutting under water immediately before the experiment and taken promptly into the nearby laboratory. Here, the pedicel was recut under water to a length of 20 mm, immediately inserted in a short piece of water-filled Teflon®-tubing (inner diam. 1.6 mm, length 20 mm) and the

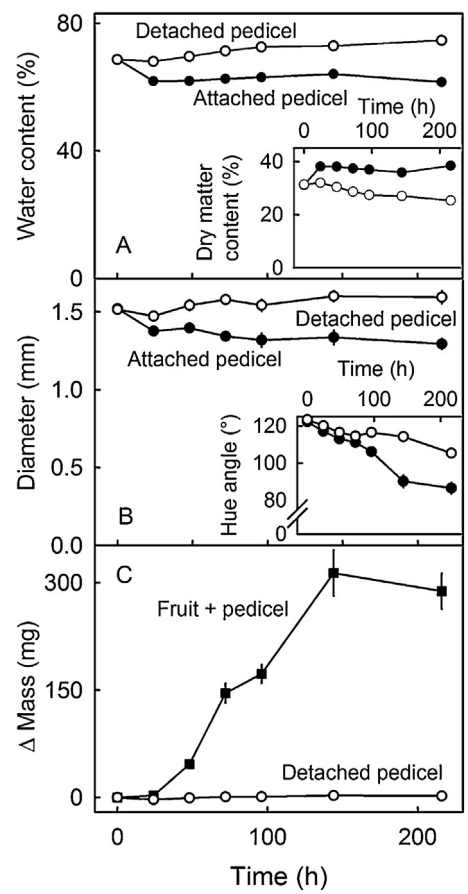

Fig. 1. Time course of change in water content (A), dry matter content (A, inset), diameter (B) and color (B, inset) of pedicels that remained attached to the fruit or of detached pedicels. (C) Change in mass of fruit with their pedicels attached and of detached pedicels.

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