Scientia Horticulturae 167 (2014) 127–134

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Indicators of plum maturity: When do plums become tasty?

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ARTICLE INFO

Article history:
Received 25 October 2013
Received in revised form 31 December 2013
Accepted 3 January 2014

Keywords:
Stone-fruit
Prunus domestica
Ripening
Taste
Firmness
Colour

ABSTRACT

The good taste of European plums (*Prunus domestica* L.) was the main focus of this research. During three fruiting seasons, indicators of ripening stages (peel and flesh colour, soluble solids content—SSC and firmness) were measured and eating quality sensoryly evaluated on four plum cultivars ('Haganta', 'Jojo', 'Stanley' and 'Toptaste'). Measurements were performed during the final 4 to 7 weeks of ripening at 3(4)- or 7-day intervals to identify the ripeness stage at which plums become tasty at optimal texture. The results indicated a high variability in pomological characteristics among different cultivars and growing seasons, especially at the ripening stage when eating quality improves. This ripening stage, when sensory quality scores shift from 2.5 on a five-step scale (lower limit taste stage, LLTS) was the start of the potential picking window (PPW), which was further analysed in detail. PPW ended when the estimated eating quality of plums exceeded a score of 4. During PPW, a change of firmness is the only useful indicator of plum maturity. Plums became tasty when they satisfied conditions in the following order: (1) fruit skin completely coloured; (2) flesh colour changed from green into characteristic colour for cultivar; (3) fruit firmness equals 15 ± 2 N.

1. Introduction

Identification of harvest date plays a key role in the agro-food chain (Bertone et al., 2012). Maturity at harvest determines the quality, potential shelf-life and consumer acceptance of fruit (Crisosto et al., 1995; Singh and Khan, 2010). Although sensory properties improve with ripening (Kader, 2008), fruits are nevertheless often picked at an early stage to enhance handling quality. Immature fruit does not possess full flavour and aroma and will never reach an excellent eating quality (Tromp, 2005).

Low consumption of plums has been attributed to low eating characteristics such as a lack of fruit ripening (Crisosto et al., 2004). To provide consumers with better-tasting plums, producers should be encouraged to harvest fruit at partially ripe to fully ripe stages (Kader, 2008) because consumers value plum fruit for its colour, taste and flavour (Louw and Theron, 2012).

A number of physiological, biochemical, and structural changes occur during ripening of fruit, resulting in modifications identified by measurement of specific physical–chemical variables (Nunes et al., 2009; Usenik et al., 2013). Plum fruit fails to produce more sugars once removed from its carbon source (Louw and Theron, 2012). Skin colour, soluble solids content (SSC), fruit firmness (firmness), titratable acidity (TA) and the occurrence of specific volatile compounds are considered to be maturity indices for plum fruit (Abdi et al., 1997; Crisosto and Valero, 2006; Prasanna et al., 2007; Nunes et al., 2009). Variability among plum cultivars is large: specific maturity parameters need to be defined for each cultivar (Nunes et al., 2009).

Skin colour is one of the most important criteria of ripening in stone fruit but not suitable for the determination of plum fruit maturity, because many genotypes develop pigmentation early in their growth (Abdi et al., 1997; Usenik et al., 2008). A wide range of variability in skin colour exists among plum cultivars (*Prunus domestica* L.) during fruit ripening and at fruit maturity (Diaz-Mula et al., 2008; Gómez and Ledbetter, 1997; Lozano et al., 2009; Usenik et al., 2009). Soluble solids content (SSC) in stone fruit is an essential quality variable (Di Miceli et al., 2010; Infante et al., 2011), which, together with titratable acids (TA) and SSC/TA ratio, has been suggested as the most reliable maturation parameters for plums (Prasanna et al., 2007; Casquero and Guerra, 2009). Firmness is a key quality parameter, since it is directly related to fruit ripeness and is often a good indicator of shelf-life potential (Valero et al., 2007). Firmness decreases significantly during ripening (Guerra et al., 2009; Guerra and Casquero, 2009; Usenik et al., 2008) and would be useful for distinguishing maturity at harvest (Guerra and Casquero, 2009, 2010; Casquero and Guerra, 2009).

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http://dx.doi.org/10.1016/j.scienta.2014.01.002

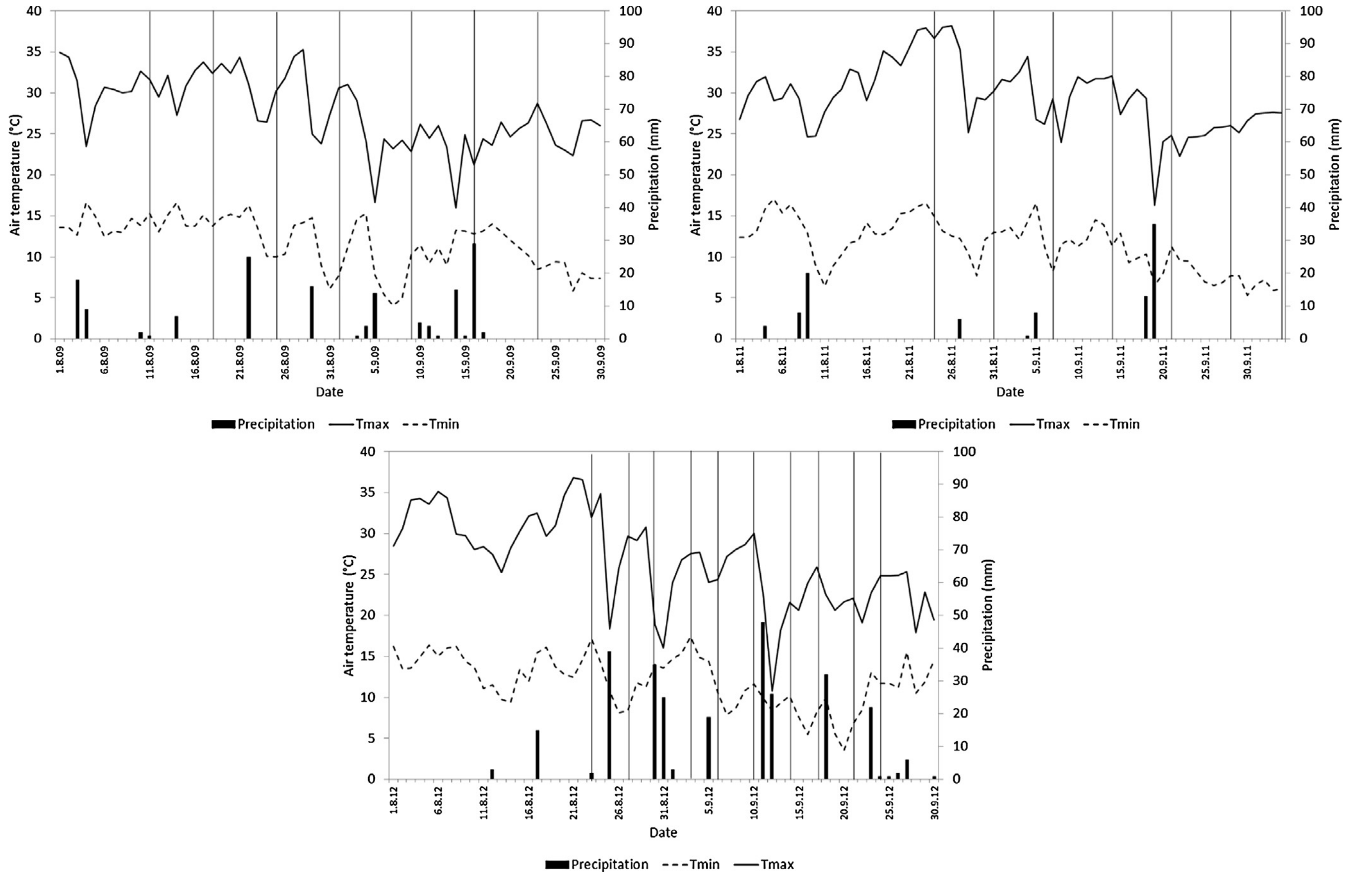

Fig. 1. Daily minimum (T_{min}), maximum air temperature (T_{max}) and precipitation with days of plum picking in 2009, 2011 and 2012 marked.

The objective of this study was to determine the degree of maturity at which plums (*P. domestica* L.) of different cultivars become tasty. The study therefore focused on the final phase of fruit ripening. The present work also focused on useful indicators of plum maturity that could be easily measured, independent of cultivar and growing season. This should help in identifying the optimal harvest ripeness of fruit, which is still a major problem in plum production.

2. Materials and methods

2.1. Fruit sampling

Over the course of three years (2009, 2011 and 2012), three experiments were performed with the plum (*P. domestica* L.) cultivars 'Haganta', 'Jojo', 'Stanley' and 'Toptaste', differing in their pomological characteristics and time of ripening. 'Toptaste' is an early ripening cultivar (dark blue skin, golden yellow flesh), 'Stanley' is a mid to late (dark blue skin, green–yellow flesh) and 'Jojo' (dark blue skin, yellow orange flesh) and 'Haganta' (blue violet skin, golden yellow flesh) are late ripening cultivars.

Plums were sampled from the experimental orchard of the Biotechnical Faculty of the University of Ljubljana, Slovenia (46°03′ latitude and 14°31′ longitude). The trees were spaced at 4 m × 2.5 m, trained as spindle and not irrigated. The average annual precipitation is 1200 mm.

In 2009, 'Haganta', 'Jojo' and 'Toptaste' were picked at 7-day intervals through the 7 weeks of ripening (from unripe fruit to tree ripe stage). In 2011, 'Haganta', 'Jojo' and 'Stanley' fruit were picked at 7-day intervals through the 7 weeks of ripening (from already fully coloured fruit until the fruit was over-ripe). In 2012, fruit were picked at 3- or 4-day intervals through the 4 ('Jojo', 'Stanley' and 'Toptaste') or 5 ('Haganta') weeks of ripening (from already fully coloured fruit until the fruit was over-ripe).

Air temperature and precipitation during the time of fruit sampling and harvest are shown on Fig. 1.

2.2. Ripening variables

For each sampling date and each cultivar, 10 fruit were picked (n = 10). On each single fruit, peel (h_{peel}) and flesh colour (h_{flesh}), firmness and soluble solids content (SSC) were measured immediately after picking. Using a Konica Minolta Portable Colour Reader CR-10 (Konica Minolta, Inc., Osaka, Japan; measuring diameter 8 mm), hue (h) was measured in fruit with an uninjured blush on two sides of each fruit, the values averaged, (h_{peel}) and in flesh (h_{flesh}). With a penetrometer (Chatillon penetrometer model DFG 50, John Chatillion & Sons, New York, U.S.A.; insertion depth 5 mm), equipped with a round jagged stainless steel probe (diameter 6 mm), firmness was measured on two sides of each fruit immediately after the measurement of h_{peel}, and the values averaged. SSC was measured in fruit juice with a digital refractometer (WM-7, Atago Co. Ltd., Tokyo, Japan).

Skin and flesh colour were evaluated visually following a six-step scale (skin: (1) purple; (2) blue–purple; (3) green–purple; (4) purple–blue; (5) blue; (6) dark blue; flesh: (1) green (GR); (2) yellow–green (Y–GR) and green–yellow (GR–Y); (3) yellow (Y); (4) golden yellow (GO–Y); (5) yellow–orange (Y–OR); (6) orange (OR)). Eating quality (taste) was assessed by experienced tasters following a five-step scale ((1) and (2) bad; (3) fair; (4) good; (5) excellent); the scores were averaged.