Scientia Horticulturae 190 (2015) 179–186

Contents lists available at ScienceDirect

Scientia Horticulturae

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

The impact of maturity, storage temperature and storage duration on sensory quality and consumer satisfaction of 'Big Top®' nectarines

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ARTICLE INFO

Article history:
Received 29 January 2015
Received in revised form 1 April 2015
Accepted 14 April 2015
Available online 15 May 2015

Keywords:
Consumer satisfaction
Fruit quality
Prunus persica
Sensory attributes
Storage temperature

ABSTRACT

This research focuses on the effect of maturity stage and storage conditions on quality and consumer satisfaction of 'Big Top®' nectarines. At harvest time, fruit were graded in three categories according to the I_{AD} index (index of absorbance difference = $A_{670} - A_{720}$) based on Vis spectroscopy. Physicochemical parameters (soluble solids concentration, titratable acidity and flesh firmness) were measured for the three maturity categories at harvest time and after up to 49 days of storage at 20, 10, 4 or −1 °C. Consumer satisfaction and sensory attributes were also measured on fruit from all three categories at harvest time, as well as on fruit from the intermediate maturity class after storage at the different tested temperatures for up to 49 days. At harvest time, consumer's satisfaction increased significantly with maturity stage at harvest, mainly due to an upper sweetness and flavour perception and higher SSC value detected in the most mature class. For short storage periods, 'Big Top®' nectarines kept at 20 °C received the highest scores for peach flavour intensity and overall acceptance. For longer storage periods, no significant differences among temperatures were observed on sensory quality or consumer satisfaction, except for fruit stored for the longest period (7 weeks), for which higher consumer acceptance was found for fruit stored at −1 °C than at 4 °C. Results also suggested that higher acceptance scores were associated mainly to more intense perception of flavour.

1. Introduction

European production of peach and nectarine in 2013 was about 3 million tonnes, 51% of which were nectarines. An important increase in the proportion of nectarine production has been observed in the last years at most peach production areas. 'Big Top®' is nowadays considered the reference nectarine cultivar in Europe for fresh consumption, known as a slow-softening rate cultivar and appreciated for its early colouration resulting in greatly coloured fruit, optimum fruit size, high sweetness, juiciness and flavour (Cano-Salazar et al., 2013a,b). Moreover, recent studies have shown that it is a particularly suitable cultivar for fresh-cut production (Cefola et al., 2014; Giné Bordonaba et al., 2014).

'Big Top®' nectarine is the most widely cultivated nectarine cultivar in Europe. To withstand handling in the packing house and marketing operations (transport, storage and retail display) these fruit have to be firm enough. Hence, they are frequently harvested before full ripeness, but such fruit often fail to develop desirable sensory attributes, and are consequently not perceived as sufficiently satisfactory by the consumer. Moreover, it has been largely documented that nectarine fruit subjected to long cold storage are prone to suffer serious quality decay, detected at the consumer level, due to the development of chilling injury symptoms, evident as mealiness, internal browning and lack of peach flavour (Crisosto et al., 1999; Lurie and Crisosto, 2005). The poor eating quality of fresh peach and nectarine transported to distant markets is one of the main current problems of the growing peach industry.

Nectarine quality has always been measured in terms of the traits of the fruit, mainly through evaluation of the physical and chemical properties that best describe the progress of maturation and ripening. Flesh firmness, superficial and ground colour, soluble solids content (SSC), and titratable acidity (TA) are the parameters used generally for defining fruit quality because they provide a common language among researchers, producers and handlers (Abbott, 1999). However, when quality is measured from the consumers' perspective, these parameters do not always match what consumers consider for deciding whether produce quality is

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http://dx.doi.org/10.1016/j.scienta.2015.04.022
0304-4238/

acceptable (Shewfelt, 1999). Consumers often buy the first time based on fruit appearance, but repeated purchases are driven by expected quality factors mainly determined by flavour compounds and texture (Crisosto et al., 2006). In general, consumers are willing to pay more for fruit with a higher hedonic score (Delgado et al., 2013), which sheds light on why harvesting at the optimum ripening stage, and storing the fruit at the optimum temperature and duration is crucial. However, there is scarce literature where the effect of storage conditions on the consumer perception had been studied through consumer tests. Thus, it is important to define quality on the basis of consumer expectations (Predieri et al., 2006).

The consumers' judgement in the food marketplace has become crucial over the recent years (Asp, 1999). The demand for high quality fruit, including excellent taste, high nutritional value and nutraceutical value, highlights the need of monitoring the effect of the postharvest chain on sensory attributes, and subsequently on consumer satisfaction.

To the best of our knowledge, no previous studies have examined the relationships between storage duration and temperature of nectarines harvested at different ripening stages and consumer perception. In the present work, 'Big Top®' nectarines from different maturity stages were exposed to different temperature and periods of storage with the objective of characterising their effect on standard quality parameters, sensory attributes and consumer satisfaction.

2. Materials and methods

2.1. Fruit material

Yellow-fleshed nectarines (*Prunus persica* L. Batsch var. *nucipersica* cv. 'Big Top®') were harvested at 109 days after full bloom (DAFB) in 2008 at a commercial orchard located in Massalcoreig (Catalonia, NE Spain) and selected for uniformity of size and absence of defects. The I_{AD} index (index of absorbance difference = $A_{670} - A_{720}$) at harvest was used to pre-sort nectarine non-destructively by Vis spectroscopy (Ziosi et al., 2008). In this work the I_{AD} index was measured using a commercial equipment (C2005d, Minolta, Valencia, Spain), while Ziosi et al. (2008) used a commercial spectrometer (S-2000, Ocean Optics, Dunedin, USA). Following sorting, fruit were classified into three different categories by decreasing values of the I_{AD} (M1: I_{AD} 0.17–0.15; M2: I_{AD} 0.14–0.12; M3: I_{AD} 0.11–0.09) and stored at 20, 10, 4 or −1 °C for up to 49 days depending on storage temperature. Out of 3750 fruit assessed in total, 898 were graded as M1, 1278 as M2, and 759 as M3. At harvest, for each maturity class, 15 and 20 fruits were used for physicochemical measurements and consumer evaluation, respectively. After each storage period, 15 fruits were also used for physicochemical measurements per temperature and maturity class (total ~ 500 fruits). In addition, for M2 class 15 fruits more were used after each storage period and temperature for consumer evaluation (total ~ 500 fruits). Physicochemical parameters (flesh firmness, SSC and TA) were measured for fruit from the three classes at harvest and periodically throughout storage, while consumer satisfaction and sensory attributes described by a consumer panel were scored for fruit from the three categories at harvest time, but only for fruit from M2 class during storage.

2.2. Physicochemical analyses

Fifteen nectarines at harvest and per combination of factors (storage temperature × storage period) were used individually for the analysis of flesh firmness, SSC and TA. If at removal the fruit was of low quality (firmness ≤ 5 N and presence of fungal decay) the experiment was over for that temperature. In that case, fruit were removed from the storage chamber and not assessed sensorially. Flesh firmness was measured on opposite sides of each fruit with a penetrometer (Effegi, Milan, Italy) fitted with an 8-mm diameter plunger tip; results were expressed in N. SSC and TA were measured in juice pressed from the whole fruit. SSC was determined with a hand-held refractometer (Atago, Tokyo, Japan), and results were expressed as %. TA was determined by titrating 10 mL of juice with 0.1 N NaOH to pH 8.1 using a pH-metre (GLP 21, Crison); results were given as g malic acid/L.

2.3. Consumer satisfaction and sensory attributes assessment

Fruit samples from each maturity stage were scored by consumers immediately after harvest. However, after storage only fruit from M2 class was sensorially analysed. After each storage temperature and period, fruit was kept for 3–4 h at room temperature in order to allow fruit to reach 20 °C before consumer's assessment. Fifteen nectarines per combination of factors (storage temperature × storage period) were used for sensory analysis. Sensory evaluations were conducted as elsewhere described (Echeverría et al., 2008). Each consumer, from a panel of 81 consumers, was asked to indicate his/her degree of liking/disliking using a nine-point hedonic scale (1, dislike extremely; 9, like extremely). In addition, consumers were asked to score how they perceived the intensity of sweetness, sourness, firmness, juiciness and flavour according to a five-point hedonic scale (1, very low intensity; 5, very high intensity). Consumers were volunteers from the staff working at the University of Lleida and IRTA (Institut de Recerca i Tecnologia Agroalimentàries), and students from the University of Lleida. The samples could be re-tasted as often as desired. All evaluations were conducted in individual booths under white illumination and at room temperature.

2.4. Statistical and multivariate analysis

A multifactorial design with storage period and temperature as factors was used to statistically analyse the results. All data were tested by analysis of variance (GLM-ANOVA procedure) with the SAS/STAT 9.1 procedures (SAS Institute Inc., 2004). Mean comparisons were performed using Tukey's LSD test at $P \leq 0.05$. Correlations between experimental variables were made using Spear-man's rank correlations and, if required, presented as Spearman's correlations coefficient (r) and P value based on a two-tailed test. Unless otherwise stated, significant differences were $P < 0.05$. Unscrambler version 9.1.2 software (CAMO, 2004) was used to develop two partial least square regression models (PLSR). The first PLSR was used as a predictive method to relate consumer's satisfaction (Y) to a set of explanatory variables (X) which contains physicochemical measures and sensory attributes. It was performed considering samples from the first week of storage. The second one was developed using samples preserved for two or more weeks of storage and its aim was to identify the variables that better can predict consumer's satisfaction. Two PLSR analyses were performed separately since during the first week we had samples

Table 1
Flesh firmness, soluble solids content (SSC) and titratable acidity (TA) of 'Big Top®' nectarines at harvest. M1, M2 and M3 represent fruit classes according to I_{AD} values.

	M1	M2	M3
Flesh firmness (N)	56.34 a	47.45 b	40.65 b
SSC (%)	11.54 b	12.03 b	13.49 a
TA (g/L malic acid)	7.96 a	6.37 b	6.51 b

Values represent means of 15 replicates. Means within each row followed by different letters are significantly different at $P \leq 0.05$ (Tukey's LSD test). M1: I_{AD} 0.17–0.15; M2: I_{AD} 0.14–0.12; M3: I_{AD} 0.11–0.09.