Scientia Horticulturae 209 (2016) 47–52

Contents lists available at ScienceDirect

Scientia Horticulturae

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

A proposal for determining the flesh softening of peach and nectarine in postharvest through simplified targeted modeling

L. Contador, M. Díaz, M. Millanao, E. Hernández, P. Shinya, C. Sáenz, R. Infante*

University of Chile, Faculty of Agricultural Sciences, Av. Santa Rosa 11315, 8820808 Santiago, Chile

ARTICLE INFO

Article history:
Received 25 February 2016
Received in revised form 2 June 2016
Accepted 10 June 2016
Available online 23 June 2016

Keywords:
Ripening
Penetration
Uniaxial compression
Flesh firmness
Modeling

ABSTRACT

Peach flesh softening is a continuous process that occurs mainly during postharvest. It allows fruit to reach the proper firmness for consumption. In this trial, it was evaluated different texture attributes of three nectarine cultivars and three peach cultivars over a 5-day period (day of harvest, and the first, second, third, and fourth days after harvest) at 20 °C using penetration and uniaxial compression tests. Through linear modeling with it was obtained the fixed and random effects and linear functions, where the slopes represent the flesh softening. Cultivars were segregated using contrast tests. It was found that the penetration test was more effective than the uniaxial compression test, as it allowed for the segregation of the genotypes into three clusters. One cluster, grouped the melting fleshed (*MF*) nectarines ('Andes Nec-1', 'Andes Nec-3', and 'Venus'), showed the fastest softening rate. The *MF* 'Sweet September' and the non-melting (*NMF*) 'Hesse' were grouped together, as they exhibited the lowest softening rate. Lastly, the *NMF* 'Andross' was alone, showing an average score. These results suggest that the different softening patterns cannot be fully explained by the *MF*/*NMF* classification. In order to facilitate the implementation of the protocol for determining softening, it was used a targeted model that focused on the most informative phase of the curve—namely, the first and third days of the evaluations. This simplified targeted model allowed to segregate the genotypes into the same original clusters, and it confirms that the analysis of only two points of evaluation is sufficient to characterize the softening rates of different peach cultivars.

1. Introduction

The texture of fruit, as an attribute of a particular fruit's entire sensory quality, is important when determining consumer preferences (Bonnin and Lahaye, 2013; Tunick, 2011). The factor that most affects peach texture is softening, which determines the sensory quality and shelf life of fruit in postharvest (Ghiani et al., 2011a,b). During this process, the cell walls forming the mesocarp are relaxed and solubilized (Hayama et al., 2006; Waldron et al., 2003), thus generating a smooth and melt texture in melting fleshed peaches (*MF*). On the other hand, non-melting peaches (*NMF*), even if they soften, remain relatively firm during postharvest (Brovelli et al., 1999; Lester et al., 1996; Yoshioka et al., 2010).

Measuring firmness in peach is useful for (1) determining the proper time to harvest (Infante, 2012), (2) monitoring postharvest fruit ripening (Zhang et al., 2010), and (3) as a parameter associated with acceptability and consumer preference (Delgado et al., 2013). The most common way to measure peach firmness is by penetrating or puncturing the flesh with a 7.9 mm probe (Infante et al., 2008). Although there are other rheological tests available, they are seldom used in fruit studies, even if they could be useful for determining other parameters of texture. Among these, single or uniaxial compression tests are commonly employed in the determination of food texture (Bourne, 2002). As it pertains to fruit, a uniaxial compression test involves pressing the sample – without destroying it – by employing a probe larger in diameter than the sample itself, thus resembling the action of gentle hand pressure placed on the fruit (Bourne, 2002). This type of analysis allows for multiple measurements of the same fruit on more than one occasion during postharvest.

In general, studies dealing with postharvest peach firmness show that this parameter is frequently associated with the content of soluble solids or with a certain background skin color; there is little research that has focused on how the flesh soften during postharvest (Cano-Salazar et al., 2013a,b; Cantin et al., 2010; Iglesias and Echeverria, 2009). Flesh softening is a continuous process, and, therefore, must integrate various measurements over time. Considering many different peach and nectarine cultivars on the market have unknown postharvest life spans, it is crucial to assess and classify the genotypes according to their softening

* Corresponding author.
E-mail address: rinfante@uchile.cl (R. Infante).

http://dx.doi.org/10.1016/j.scienta.2016.06.015
0304-4238/

patterns. The aim of this paper is to analyze and compare the softening patterns of different peach cultivars during shelf lives and to determine a simple and reliable methodology to measure their softening.

2. Materials and methods

2.1. Fruit sorting

The trial was conducted during the 2014 and 2015 seasons. It was harvested four *MF* cultivars and two *NMF* in physiologically ripe, pre-climacteric stage (Contador et al., 2011; Zhang et al., 2010). In the first season, it was analyzed the peach cultivars 'Andross' (*NMF*), and the nectarine 'Andes Nec-1' (*MF*), 'Andes Nec-3' (*MF*), and 'Venus' (*MF*). In the second season, it was analyzed the peach cultivars 'Hesse' (*NMF*) and 'Sweet September' (*MF*). Immediately after harvesting, the fruit were transported to the lab, and their ripeness levels were homogenized by sorting them in accordance with the chlorophyll absorbance index (I_{AD}), as measured on both cheeks of each fruit with a Da-Meter device (Sinteleia, Bologna, Italy).

The fruit were sorted using a range between 1 and 1.5 units of I_{AD} (Shinya et al., 2013). I_{AD} is an index that measures the difference in absorbance levels of chlorophyll at two wavelengths – A670 and A720 – which have been reported to have significant correlations with the flesh firmness and the angle hue color in peach, demonstrating that it is an effective, non-destructive tool for determining peach ripeness (Shinya et al., 2013; Ziosi et al., 2008). Lastly, the fruit were transferred to a ripening chamber at 20 °C and 90% RH for four days. Twenty fruit of each cultivar were separated for the uniaxial compression test, and the rest were withdrawn daily in batches of 15 fruit to perform the destructive penetration test.

2.2. Uniaxial compression test

Twenty fruit were subjected to uniaxial compression tests on the day of harvest and on the first, second, third, and fourth days after harvest. The measurements were made in the equatorial zone of each fruit using a TA.XT Plus Texture Analyser (Stable Micro Systems, Surrey, UK), and using a wide plunger (20 mm diameter) that deforms the whole fruit. The haul of the plunger ran 1 mm deep from the time it makes contact with the skin and at a speed of 5 mm s^{-1}. To avoid possible mechanical damage induced by the measurement procedure, the skin location where the plunger was in contact with the fruit was first marked with an indelible ink pen (Sharpie Fine Point Permanent) so that each measurement would be slightly separated from the former one. This evaluation allowed assessing the maximum force (N) of the uniaxial compression.

2.3. Penetration test

At harvest, and on the first, second, third, and fourth days after harvest, 15 fruit were evaluated on each day. After removing the epidermis with a scalpel, they were subjected to a puncture test with a 7.9 mm plunger using a TA-XT Plus texture analyzer (Stable Micro Systems, Surrey, UK). The penetration depth was 10 mm, and the probe ran at a constant speed of 5 mm s^{-1}. This evaluation allowed to assess the fruits' maximum force (N); final force (N); total area (area under the curve, or work performed by the probe to penetrate tissue in N m); maximum force area (area under the curve up to the maximum force in N m); linear distance (length of an imaginary line connecting all points of the curve); number of peaks; and young modulus (tissue elasticity in N m^{-1}).

2.4. Data analysis

To characterize the ripeness levels at harvest, ANOVA was performed, based on the variable maximum force (N), as measured by the penetration test with a 7.9 mm plunger. This test corresponds to the most common parameter used by the peach industry, which is assessed with a portable penetrometer. The maximum force means were separated by a Fishers Least Significant Difference (LSD) test (5%). Based on the penetration tests, and before the linear model was built, the most relevant flesh-softening parameter was chosen. Next, biplot principal component analysis (PCA) was performed, and this was analyzed using only the vectors and their relative significance according to their projections on the axes. The results of both tests (uniaxial compression and penetration) were adjusted to linear modeling with fixed and random effects. The model for analyzing the uniaxial compression test was the following:

$$Y_{ijkl} = \mu + D_i + V_J + (D \times V)_{ij} + f_k + t_l + \varepsilon_{ijkl},$$

where Y = maximum force (N); D = evaluation day (harvest, first, second, third, fourth day after harvest); V = cultivar; f = fruit; and t = season (2014; 2015). The day (D) and cultivar (V) were the fixed effects, while the fruit (f) and time (t) were the random effects that added unplanned variability to the model, and, in this case, could be calculated regardless of the experimental error ε. Thus the results of the predicted values are explained by the fixed factors of the model. As the penetration test analysis is a destructive test, it is not possible to estimate the variability of the force ascribable to the fruit, since daily 15 different fruit samples were measured, and, therefore, this variance is attributed to the experimental error ε; the model is the following:

$$Y_{ijk} = \mu + D_i + V_j + (D \times V)_{ij} + t_k + \varepsilon_{ijk},$$

where Y = maximum force (N); D = evaluation day (harvest, first, second, third, and fourth day after harvest); V = cultivar; and t = season (2014; 2015).

The linear functions of softening for each cultivar were generated based on these models. Following this, the slopes were analyzed, i.e., the loss of firmness over time, also known as the softening rate. In order to find the differences between the slopes, it was executed contrast analysis, which also allowed comparing groups of treatments for the *MF*/*NMF* typologies. The results of both models were analyzed; the best model was the one that was able to segregate more cultivars according to the softening rates. Further, it was calculated a new model, targeted at the most informative phase of the curve. Statistical analysis was completed using the InfoStat version 2014 statistical software (Grupo InfoStat, Córdoba, Argentina).

3. Results and discussion

3.1. Firmness at harvest

The optimum range of flesh firmness at harvest for *MF* peach varies between 45 and 53 N (Crisosto, 1994). In general terms, other studies indicate that the flesh firmness of *MF* and *NMF* peaches should be between 40 and 65 N, depending on the variety (Ghiani et al., 2011a,b). Accordingly, all varieties used in this trial were within the optimal range of firmness at harvest (Table 1).

3.2. Principal component analysis (PCA)

The variables that best represent the softening patterns of peach cultivars during their shelf lives are the following: Young modulus, final force, maximum force, and maximum force area. This is because their vectors were grouped together and follow the largest