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Instrumental and Sensory Evaluation of Eating Quality of Peaches and Nectarines

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Summary

The influence of flesh firmness on consumer acceptance and its relationship with total soluble solids concentration (TSSC), titratable acidity (TTA) and sensory analysis was studied to understand their interaction in determining acceptance judgments, for different organoleptic typologies of peaches and nectarines. The investigation was carried out during summer 2006 on fruit of 'September Sun' and 'Sweet September' (low acid) peach (*Prunus persica* (L.) Batsch), and 'Maria Dolce' (low acid) and 'Venus' nectarines (*Prunus persica* (L.) Batsch, var. *nucipersica*). Sensory descriptors for peaches and nectarines were Flesh firmness, Sweetness, Sourness, Aroma, and Acceptability. The panel was able to discriminate different fruit ripening stages, in terms of fruit firmness, aroma and sweetness and to relate those parameters to fruit acceptability. 'Maria Dolce', 'Venus' and 'September Sun' fruit ranging from 3.2 to 5.3 kg cm^{-2} of flesh firmness, were accepted by the panel, while acceptability of low-acid fruit of 'Sweet September' was related to their aroma and firmness. Values of flesh firmness higher than 5.5 kg cm^{-2} always resulted in unacceptable fruit quality.

Key words. *Prunus persica* L. – *Prunus persica* L. var. *nucipersica* – ripening stage – panel – chemical analysis – firmness

Introduction

The continuous selection and supply of new peach and nectarine cultivars (Byrne 2003) should be accompanied by more information to support consumer's choice in terms of fruit eating quality. In fact, fruit with similar shape, size and colour may deeply differ in taste and aroma and consumers are more than often unable to recognize most of the cultivars (Harker et al. 2003). Moreover, quality specifications for peach market mainly rely on fruit size and peel colour, while fruit ripening stage at commercial harvest time is the most important source of variability affecting consumer's requirements and satisfaction (Crisosto et al. 1998; Kader 1999). Inadequate strategies of fruit marketing, i.e. a too early harvest, is, in fact, responsible for consumer dissatisfaction, due to lack of flavour and poor textural characteristics (Bruhn et al. 1991).

In order to ensure consumer satisfaction, the ideal fruit quality index should compound, physical, chemical, nutraceutic and organoleptic parameters. Crisosto et al. (2004) used fruit firmness to establish critical thresholds of fruit eating quality and to avoid bruises of "tree ripe" fruit. Hilaire (2003) proposed a single quality index based on soluble solid content; Crisosto et al. (2006) proposed the ratio between soluble solids content and titratable acidity as an useful index, able to describe and segregate peach cultivars into organoleptic groups and to supply market with adequate fruit quality.

To better understand consumer acceptance, it is critical to know the relationship between taste and flesh firmness, since fruit firmness determines consumer's choice and satisfaction (Rettke et al. 2004). As a rule of thumb, the softer the peach fruit the higher its acceptability in terms of juiciness and taste (Delgado 1998), and, indeed, values of flesh firmness as low as 1.3 kg cm^{-2} were reported as optimal for peach fruit consumption in Italy (Pratella 1998).

However, it is important to define for the different groups of peach and nectarines how taste, flavour and aroma (i.e. consumer's acceptability) change with fruit firmness. Sensory evaluation, with appropriate descriptors, is the most reliable approach to measure consumer preference and satisfaction (Pecore and Kellen 2002).

The aim of this experiment was to study the influence of flesh firmness on consumer acceptance, by coupling the instrumental measurement of fruit quality with sensory analysis to measure their interaction in determining acceptance judgments, for different organoleptic types of peaches and nectarines.

Materials and Methods

Composition and training of the panel

Twenty potential candidates for panel composition were selected and 15 were recruited, during summer 2006, at

the Department of Plant Science of the Universidad de Chile, Santiago. None of each of candidates had any previous experience in sensory analysis and panel testing.

These potential assessors received a 1-day long training on principles and techniques of fruit sensory analysis. Participants were involved in developing descriptors for quality parameters of fruit of various yellow and white flesh peaches and nectarines cultivars, sorted at different maturity stages (Brovelli et al. 1999).

Sensory testing specifications with a linear, non-structured scale, which measures the intensity of a given stimulus, were presented to participants and they were trained to use the scale properly (Meilgaard et al. 1999). Assessors were not informed about the ultimate goal of the research.

Product samples and analysis

The investigation was carried out during summer 2006 on fruit of 8-year-old, vase-shaped trees of two peach (*Prunus persica* (L.) Batsch) and two nectarine cultivars (*Prunus persica* (L.) Batsch, var. *nucipersica*) grafted onto 'Nemaguard' rootstock and grown in a commercial orchard located in the Provincia of Santiago. The peach cultivars were 'September Sun' (medium acid, yellow flesh freestone peach) and 'Sweet September' (low acid, yellow-fleshed freestone peach); the nectarine cultivars were 'Maria Dolce', (low acid, honey-flavour, yellow flesh) (Bellini 1994) and 'Venus' (equilibrated sugar/sourness flavour, yellow flesh). Fruit were harvested at the local commercial maturity stage, defined according to the skin ground colour and over colour visual estimation, with a visual assessment. They were immediately shipped to the laboratory where they were sorted to eliminate defective or wounded samples and then placed in plastic boxes (25 per box).

The experiment was performed on 100 fruits per cultivar. Immediately after being harvested, fruit was transferred to a cold storage room at 0 °C and 90 % relative humidity (RH) for 1–2 day and then kept at 20 °C and 70–75 % RH, for 1–2 days, to achieve different ripening stages. The fourth day, they were sampled to measure flesh firmness at fruit cheeks, with a manual penetrometer (Effigi, Italy) with a 7.9 mm tip and definitively sorted in 4 classes for panel test: F1, F2, F3, F4. The classes for each cultivar were defined as reported in Table 1. Each class was composed by at least 20 fruits.

Total soluble solids content (TSSC) was measured on each of the fruit with a digital refractometer (ATAGO Pocket Pal-1, Japan); titratable acidity (TTA) was measured, as malic acid, on four homogenised samples (10 ml) of 5 fruits per class (Easy Titroline, Schott, Germany); TSSC/TTA was then calculated. Immediately after being sorted, fruits of the same cultivar at different ripening stages were sliced and blind samples were placed on different plates, specifically labelled. Each plate contained two slices of fruit per different ripening stage; all assessors tasted all samples, choosing samples randomly from their plate.

Panel test

Each of the 15 selected assessors was requested to taste four slices of different fruit sorted by stage of ripeness (F1, F2, F3 and F4). Samples from the same fruit were tested by different assessors. Water and crackers were available to clean mouth after every sample testing.

Sensory descriptors developed during the general training session were adopted on testing specification. Sensory descriptors for peaches and nectarines were: Flesh firmness, Sweetness, Sourness, Aroma intensity. Few and simple descriptors were chosen, considering the limited experience of the panel; moreover, these descriptors could be easily related with analytical measurement of fruit (Meilgaard et al. 1999). The panellists were guided to taste the fruit with and without the possibility of perceiving its aroma, to be aware of its perception (Jellinek 1985).

Acceptability assessment was used to understand the influence of single characteristics on overall liking, and represents just an indicative value of threshold acceptability for consumers (Konopacka and Plocharski 2004). Finally, assessors could express their own particular note, regarding texture, flavour and aroma.

The non-structured scale used by the assessors was 10 cm in length, with anchors 1 cm from two ends. The left end of the scale corresponded to zero amount of the stimulus while the right end represented a very strong level of the stimulus (Stone and Sidel 1992). Panellists used the line scale by placing a mark on to represent the perceived stimulus of an attribute. The marks from line scales were converted to numbers by manually measuring the position of each mark using a ruler.

Data analysis

Instrumental and sensory data were processed for analysis of variance by SYSTAT (SSCS© Inc.) software. Means comparison were performed by Tukey's test at $P \leq 0.05$ %.

Panel evaluations were tested through two way ANOVA, considering flesh firmness (ripening stage) and assessors as possible sources of variability (Lespinasse et al. 2002) for each of the four cultivar examined, since the idea was not to compare cultivar performance. Acceptability judgements were related with sensory and instrumental data by a Pearson's correlation matrix. Correlations between measured fruit parameters (flesh firmness; TSS and TSS/TTA) and panel acceptability was done considering the mean values for each of the cultivar tested. Fruit of different ripening classes (F1, F2, F3, F4) was considered acceptable when no statistical differences occurred in relation to the ripest, F1, fruit which was considered acceptable (scale value > 5).

Results

Sorting fruit of 'Venus' and 'Maria Dolce' nectarines and 'September Sun' and 'Sweet September' peaches by flesh firmness (F1, F2, F3, F4) resulted in significant differences of TSSC, TTA and their ratio, according to cultivar and organoleptic typologies (regular and low-acid) (Table 1). The range of variability of fruit firmness was much higher for fruit of 'Venus' and 'September Sun' than for the low-acid fruit (Table 1). The low-acid fruit of 'Maria Dolce' and 'Sweet September' were very different in terms of TTA and TSSC/TTA, while their TSS did not differ as much. On the other hand, fruit of 'Venus' and 'September Sun' were very similar in TSS, TTA and, as a consequence, in their ratio (Table 1).

At the earliest stages of ripening (F4) low-acid fruit of 'Maria Dolce' and 'Sweet September' had the highest TTA

Table 1. Measured parameters for fruits of the nectarine (*Prunus persica* L. var. *nucipersica*) cultivars 'Maria Dolce' and 'Venus', and for fruit of the peach (*Prunus persica* L.) cultivars 'Sweet September' and 'September Sun' sorted on the base of flesh firmness (2006).

	Flesh firmness (kg cm^{-2})			TSSC	TTA	TSSC/TTA
	Minimum	Maximum	Mean	(°Brix)	(% malic acid)	
'Maria Dolce'						
F1	2.6	3.8	3.2 a	15.1 b	0.36 a	41.9 b
F2	3.9	4.8	4.4 b	14.4 b	0.35 a	41.1 b
F3	4.9	5.8	5.3 c	14.3 b	0.35 a	40.8 b
F4	6.0	7.5	6.7 d	13.4 a	0.42 b	31.9 a
'Venus'						
F1	2.0	3.2	2.4 a	12.2 c	0.65 a	18.8 c
F2	3.3	4.5	3.7 b	12.6 c	0.65 a	19.4 c
F3	5.4	6.8	6.4 c	11.6 b	0.84 b	13.8 b
F4	7.0	8.3	8.0 d	10.5 a	0.86 b	12.2 c
'Sweet September'						
F1	3.9	5.2	4.6 a	14.1 a	0.23 a	61.3 b
F2	5.3	6.5	5.6 b	14.1 a	0.23 a	61.3 b
F3	6.6	7.5	6.9 c	14.3 a	0.23 a	62.2 b
F4	7.6	8.2	7.9 d	13.4 b	0.29 b	46.9 b
'September Sun'						
F1	2.8	4.2	3.3 a	12.6 a	0.69 b	18.3 b
F2	4.3	5.8	5.3 b	12.2 a	0.61 a	19.8 b
F3	6.2	7.3	6.9 c	11.7 b	0.82 c	14.2 a
F4	7.5	8.5	8.2 d	11.8 b	0.88 d	13.4 a

Values in each row within cultivars. having different letters are significantly different from one another at $P < 0.05$ (Tukey's Test); ns = not significant

and the lowest TSSC and TSSC/TTA, while no differences occurred when fruit became softer. On the other hand, the wide firmness range of 'Venus' and 'September Sun' fruit resulted in significant differences in terms of TSSC, TTA and TSSC/TTA between ripe fruit (F1 and F2) and very firm and unripe fruit (F3 and F4) (Table 1).

The panel was able to sort fruit of all cultivars by the same ripening classes defined with the analytical measurement of flesh firmness. In other words, panel evaluation fitted the analytical rating of flesh firmness in F1, F2, F3 and F4 classes (Table 2). The assessor effect was significant for some descriptors of the four cultivar tested but for firmness of 'Venus' and 'September Sun' and for sweetness of 'Venus' (data not shown).

The panel was unable to distinguish the acidity of low-acid fruit at different ripening stages (Table 2), but was able to score fruit sweetness in a good accordance with the measured TSSC (Table 1, 3). The aroma perception changed closely with firmness and sweetness (Table 2). Panel acceptability of 'Maria Dolce' fruit did not change significantly when measured flesh firmness ranged from 3.2 to 5.3 kg cm^{-2}. This is most likely related to TSSC/TTA ratio of fruit of those ripening stages (F1, F2, F3) (Table 2, 3).

Acceptability of F1 and F2 Venus fruit was three times higher than F3 and F4 ones whose firmness ranged from 6.4 to 8.0 kg cm^{-2}. Unripe (F3 and F4) 'September Sun' fruit was rated as poorly acceptable by the panel, while F1 and F2 (flesh firmness ranging from 3.3 to 5.3 kg cm^{-2}) fruit was the most acceptable ones in relation to the much higher TSSC/TTA ratio (Table 1) and aroma. As mentioned before, 'Sweet September' showed no variability in terms of TSSC, TTA and their ratio, but for F4 fruit (Table 1); however, the panel rated F1 and F2 fruit more acceptable than F3 and F4 (Table 2) and this is likely to be related to their aroma (Table 1) which is significantly lower in unripe, firm, F3 and F4 fruit.

Panel's acceptability was highly correlated with fruit aroma (Table 3, Fig. 1) and sweetness (Fig. 2), and inversely related to flesh firmness (Table 3, Fig. 3) and TTA (Table 3); fruit acceptability increased with TSSC/TTA ratio (Fig. 4), for all cultivars but 'Sweet September' (Table 3). The relation between panel acceptability and TSSC changed with cultivar (Table 3). Sweetness perception increased when the TSSC/TTA increased (Fig. 5).

Discussions

The panel was able to discriminate different fruit ripening stages, in terms of fruit firmness, aroma and sweetness and to relate those parameters to fruit acceptability,

Table 2. Panel sensory assessments for fruits of the nectarine (*Prunus persica* L. var. *nucipersica*) cultivars 'Maria Dolce' and 'Venus', and for fruit of the peach (*Prunus persica* L.) cultivars 'Sweet September' and 'September Sun' sorted on the base of flesh firmness (2006). Data are means out of 15 panellists' judgements.

	Flesh firmness	Sweetness	Acidity	Aroma	Acceptability
'Maria Dolce'					
F1	4.4 a	6.3 c	2.5 ns	4.3 b	6.1 b
F2	5.7 b	4.6 c	2.8	3.8 b	4.7 b
F3	7.8 c	4.0 b	2.6	3.6 b	3.9 b
F4	8.5 d	3.0 a	2.3	2.3 a	2.6 a
'Venus'					
F1	2.5 a	4.8 c	3.2 a	5.4 b	5.2 c
F2	4.6 a	3.7 c	4.3 a	4.1 b	5.1 c
F3	8.6 b	1.3 b	7.1 b	2.2 a	1.7 b
F4	8.9 c	0.9 a	7.3 b	2.1 a	1.2 a
'Sweet September'					
F1	2.8 a	5.4 c	2.0 ns	3.7 b	5.1 b
F2	4.7 a	4.3 b	2.4	3.0 b	4.1 b
F3	6.2 b	2.6 a	1.8	1.7 a	2.3 a
F4	6.7 c	2.5 a	2.1	1.4 a	2.4 a
'September Sun'					
F1	2.9 a	5.2 c	4.8 a	4.9 c	6.4 c
F2	5.7 b	3.5 b	4.7 a	3.9 c	4.6 c
F3	6.1 c	3.0 b	5.1 b	3.3 b	3.1 b
F4	7.7 c	1.4 a	5.8 b	2.5 a	1.7 a

Values in each row within cultivars. having different letters are significantly different from one another at $p < 0.05$ (Tukey's Test); ns = not significant

Table 3. Correlation between measured fruit parameters and panel acceptability for fruits of the nectarine (*Prunus persica* L. var. *nucipersica*) cultivars 'Maria Dolce' and 'Venus', and for fruit of the peach (*Prunus persica* L.) cultivars 'Sweet September' and 'September Sun' (2006).

Panel acceptability	Flesh firmness	TSSC	TTA	TTSC/TTA	Aroma
'Maria Dolce'	−0.99	0.98	−0.71	0.86	0.96
'Venus'	−0.96	0.89	−1.00	0.99	0.95
'Sweet September'	−0.95	0.32	−0.53	0.48	0.98
'September Sun'	−0.99	0.92	−0.80	0.82	0.99

suggesting that this laboratory approach could represent an useful indication of consumer satisfaction (Konopacka and Plocharski 2004).

The assessor's effect, that proved to be significant for some of sensory descriptors, may depend on the very short training period of the panel and indicate a different use of the linear unstructured scale, considering that fruit for each maturity class was very homogenous (Lespinasse et al. 2002). However, some variation among assessors is acceptable in sensory analysis (Naes 1991).

These results should be validated by a consumer test (Kader 1999) that could investigate the relationship between acceptability and some components of peach fruit taste, such as fruit firmness, total soluble solids content and titratable acidity (Hoehn et al. 2005).

There was no correlation between mesured flesh firmness and TSCC fruit content, while sensory firmness and sweetness were related (data not shown). The rationale for this apparent discrepancy is related to the fact that assessors perceived fruit sweetness on the basis of the TSSC/TTA ratio as explained by Fig. 5. This is particularly true for peaches with a regular acid content.

The relation between acceptability and sugar/acid ratio could provide an eating quality index (Crisosto et al. 2005, 2006), but since it depends on genotype, it should be defined for each cultivar or, at least, for the

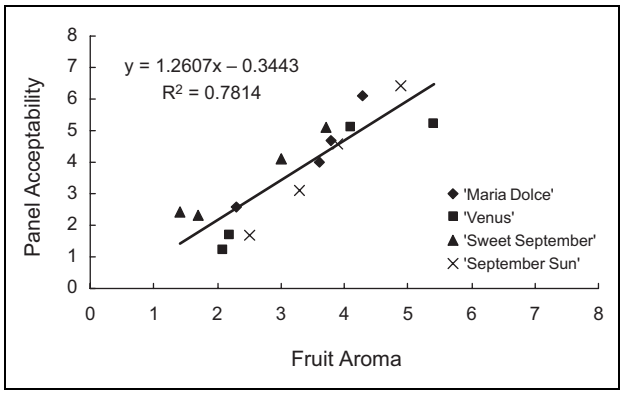


Fig. 1. Correlation between fruit aroma and panel acceptability for the nectarine (*Prunus persica* L. var. *nucipersica*) cultivars 'Maria Dolce' and 'Venus', and for the peach (*Prunus persica* L.) cultivars 'September Sun' and 'Sweet September'.

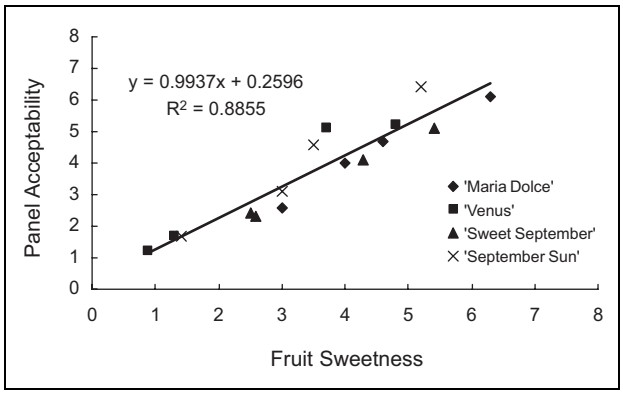


Fig. 2. Correlation between fruit sweetness and panel acceptability for the nectarine (*Prunus persica* L. var. *nucipersica*) cultivars 'Maria Dolce' and 'Venus', and for the peach (*Prunus persica* L.) cultivars 'September Sun' and 'Sweet September'.

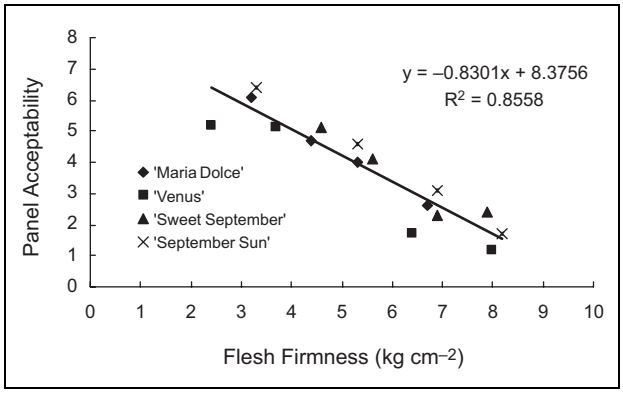


Fig. 3. Correlation between flesh firmness and panel acceptability for fruits of the nectarine (*Prunus persica* L. var. *nucipersica*) cultivars 'Maria Dolce' and 'Venus', and for fruits of the peach (*Prunus persica* L.) cultivar 'September Sun' and 'Sweet September'.

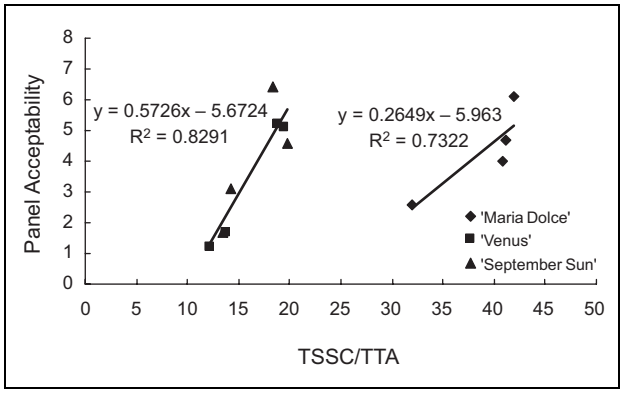


Fig. 4. Correlation between fruit total soluble solids content *vs.* titratable acidity ratio (TSSC/TTA) and panel acceptability for the nectarine (*Prunus persica* L. var. *nucipersica*) cultivars 'Maria Dolce' and 'Venus', and the peach (*Prunus persica* L.) cultivar 'September Sun'.

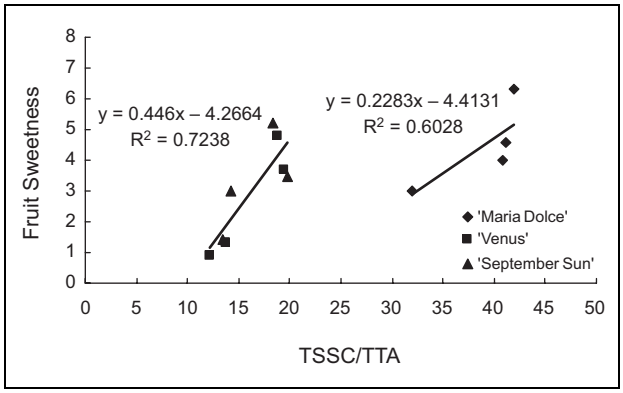


Fig. 5. Correlation between fruit total soluble solids content *vs.* titratable acidity ratio (TSSC/TTA) and fruit sweetness for the nectarine (*Prunus persica* L. var. *nucipersica*) cultivars 'Maria Dolce' and 'Venus', and for fruits of the peach (*Prunus persica* L.) cultivar 'September Sun'.

different organoleptic groups. In fact, our panel judged quite similar in acceptability 'Maria Dolce', 'Venus' and 'September Sun' fruit, ranging from 3.2 to 5.3 kg cm^{-2} of flesh firmness, as long as they had a high sugar content, sugar/acid ratio and aroma, while acceptability of low-acid F1 and F2 fruit of Sweet September was not related to their high TSSC/TTA but to their aroma and to a lower firmness than F3 and F4 ones.

Values of flesh firmness higher than 5.5 kg cm^{-2} always resulted in unacceptable fruit quality.

Fruit of the 'Caterin' peach cultivar within a range fruit firmness of 4.7 to 2.8 kg 0.5 cm^{-2} received by the panel the best sensory attributes (Cascales et al. 2005). Crisosto et al. (2006) considered the sugar/acid ratio a useful marker of acceptable taste quality. However, our data indicate that a threshold TSSC/TTA value cannot be used as a single marker for eating quality, since it may range greatly among cultivars. Eventually, fruit aroma could be the real limiting factor in determining eating quality of some low-acid peach cultivars (Delgado 1998).

Sensory analysis provided useful information for fruit quality management, coupling consumer related features to measured quality indices.

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