Sensory profiles of Various Stored Fruit Species are Affected by Maturity Class Assessed by Time-resolved Reflectance Spectroscopy at Harvest

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Abstract

The absorption coefficient measured at harvest at 670nm (μ_a670) by time-resolved reflectance spectroscopy (TRS) is a non destructive maturity index used to evaluate the biological age of fruit, i.e., the fruit maturity stage. The μ_a670 was successfully used to segregate nectarine, apple and mango fruit into maturity classes each one having distinctive ripening behaviors. Aiming at studying the influence of TRS maturity class assessed at harvest on the sensory profiles of various fruit species after storage, 'Jonagored' apples, 'Abbé Fétel' pears, 'Morsiani 90' nectarines and 'Spring Belle' peaches were measured at harvest by TRS at 670nm, ranked on the basis of decreasing μ_a670 (increasing maturity) and classified as less (LeM), medium and more (MoM) mature. Then fruit were randomized into batches of 30 fruits, each one corresponding to a storage atmosphere (apples: CA, NA; pears: CA, NA, DCA) or to a storage temperature (peaches, nectarines: 0°C, 4°C). After storage, fruit were put in shelf life at 20°C to reach the ripening degree for consumption. Sensory analyses (QDA profiles) were carried out on LeM and MoM fruit using a panel of 10 assessors. Our results indicate that, for all the species, besides the influence of storage conditions, there was also a great influence of TRS maturity classification at harvest. MoM apples and pears developed physiological disorders such as mealiness and graininess when stored in NA, whereas showed well balanced sensory characteristics when stored in CA and DCA, becoming after storage soft, juicy, sweet, but sour enough. MoM nectarines stored both at 0°C and 4°C became woolly, while the LeM ones stored at 0°C developed the best sensory characteristics. MoM peaches stored at 0°C showed the best sensory profile and the LeM ones stored at 4°C the worst. So TRS maturity classification at harvest can give some indications on the best storage conditions in order to obtain fruit with sensory characteristics than can satisfy the consumer.

INTRODUCTION

Time-resolved Reflectance Spectroscopy (TRS), a non destructive technique which probes fruit pulp at a depth of 1-2 cm, provides the simultaneous quantification of the optical properties (absorption and reduced scattering coefficients) of diffusive media (Cubeddu et al., 2001). TRS has been used to detect internal attributes related to maturity, texture and cell wall structure as well as internal defects and disorders in intact fruit (Eccher Zerbini et al., 2005b; Vanoli et al., 2009 and 2010). The absorption coefficient (μ_a) measured at harvest at 630-670 nm, near the chlorophyll peak, allowed the selection of fruit of different maturity degrees in apples, pears, nectarines and mangoes (Vanoli et al., 2010; Pereira et al., 2010). Fruit classified at harvest according to TRS showed different quality attributes as regards chemical composition and sensory characteristics. Nectarines with different μ_a670 values showed distinctive sugar, acid and aroma compositions (Jacob et al., 2006; Vanoli et al., 2008b). Apples and nectarines classified at harvest as more mature (low μ_a values) were perceived sweeter, more aromatic and less sour than fruits sorted as less mature (high μ_a values) and were more appreciated by the assessors (Vanoli et al., 2005 and 2008a). Apples having a dry-mealy texture with no flavor were discriminated from flavoured apples with a juicy texture by using absorption coefficients measured in the 630-780 nm range (Rizzolo et al., 2010). Similarly, TRS measurements at 670 and 780 nm were able to differentiate between healthy and nectarines with woolliness, internal browning or internal bleeding (Lurie et al., 2011).

This research aimed at studying the sensory profiles of various fruit species after storage in different atmospheres and temperatures in relation to the maturity class measured by TRS at harvest.

MATERIALS AND METHODS

Fruit

The following fruit species were considered: i) apples (*Malus×domestica* 'Jonagored'), season 2003, from two harvest date (H1=early harvest; H2=commercial harvest), stored at +1°C for 5 months in normal (NA) and controlled (CA, 1% O_2 + 2% CO_2) atmospheres; ii) late-maturing nectarines (*Prunus persica* L. 'Morsiani90'), season 2009, after 4 weeks of storage at 0°C and 4°C; iii) early-maturing peaches (*Prunus persica* L. 'Spring Belle'), season 2010, after 4 weeks of storage at 0°C and 4°C; and iv) pears (*Pyrus communis* L. 'Abbé Fétel'), season 2004, stored for 3 months at −0.5°C in NA, CA (2% O_2 + 0.7% CO_2) and dynamically-controlled atmosphere (DCA, 0.7% O_2 + 0.3% CO_2).

Experimental plan

For each species, fruit (apples, n=60/harvest; nectarines and peaches, n=60; pears, n=180) were individually measured at harvest on two sides by TRS at 670 nm using a portable prototype built at Politecnico di Milano (Torricelli et al., 2008), and the μ_a values were averaged per fruit. Then, fruit were ranked on the basis of decreasing μ_a (increasing maturity) and were randomized into 30-fruit samples all having 10 fruit of less (LeM), medium and more mature (MoM) TRS maturity classes in order to have in each sample the whole range of μ_a. Each sample was assigned to one storage treatment. After storage and before sensory analysis, all samples were kept in shelf life at 20°C to reach the ripening degree for consumption: apples, 7 days; late-maturing nectarines, 5 days; early-maturing peaches, 3 days; pears, 4 days.

Sensory analyses

Sensory analyses were carried out in a sensory lab using a panel of ten short-term-trained judges. In each session, one peeled slice/fruit of LeM and MoM classes from each sample, coded with three digit random numbers, were presented to each panellist. In order to have the same differences in maturity (μ_a670) among fruit for all the ten assessors, fruit presented to each panellist had the same rank position in the samples. At the beginning of each session, a slice of a fruit not included in the experimental plan was tasted to eliminate the first tasting effect. Drinking water was provided as a palate cleaner between samples. Each sample was evaluated for the intensity of attributes related to fruit structure (all species: firm, juicy; apples: crispy, mealy; pears: grainy; peaches and nectarines: woolly), taste and flavour (all species: sweet, sour, aromatic; pears: astringent) and the acceptability using 120 mm unstructured line scales with anchors at 12 mm from the extremes (low, high).

Statistical analysis

For each species, data were submitted to multifactor ANOVA (Statgraphics ver.7, Manugistic Inc., Rockville, MD, USA) considering the TRS maturity class (all species), storage temperature (peaches and nectarines), storage atmosphere (apples and pears) and harvest date (apples) and their interactions as sources of variation. Prior to statistical analyses, the rating scores of each attribute were standardized by panellist to mean equal to 50 and standard deviation equal to 21 in order to remove the variability due to panellists using different parts of the scale. For each attribute, mean scores reported in tables and graphs followed by different letters are statistically different at $P \leq 0.05$ (Tukey's test).

RESULTS AND DISCUSSION

Apples

Statistical analysis of sensory attributes showed that harvest date, storage atmosphere and TRS maturity classification affected firmness, crispiness, mealiness and sourness, and did not influence aroma (Table 1). On the average, H1 apples were firmer, more crispy and sourer and less mealy than H2 fruit and were more appreciated by assessors. NA stored apples were described less firm, crispy, juicy and sour, and more mealy and were judged less pleasant than CA stored ones, similarly to what previously found by Vanoli et al. (2005) and Rizzolo et al. (2010). LeM fruit were characterized by higher firmness, crispiness, juiciness and sourness and lower mealiness and sweetness than MoM apples (Table 1). Comparing the sensory profiles, TRS maturity class showed the greatest differences for all the sensory attribute (except aromatic) in H1 apples stored in CA (Fig. 1). On the contrary, the sensory profiles of NA apples differed only for crispy, mealy and sour for H2 fruit and for sweet for H1 ones (Fig. 1). At both harvest dates, LeM-CA apples showed the highest scores for firm, crispy and sour and the lowest for mealy; the opposite was true for MoM-NA apples, indicating that after 5 months of storage, apples classified as LeM at harvest and stored in CA were perceived as the least mature, while apples classified as MoM at harvest and stored in NA developed the typical taste and flavor of a ripe fruit.

Nectarines and peaches

Both TRS maturity class and storage temperature significantly influenced firmness, sourness, aroma and acceptance in 'Morsiani90' nectarines (Table 2), while in 'Spring Belle' peaches, firmness was influenced by both factors, juiciness and acceptance by TRS maturity class and woolliness by storage temperature (Table 3). On the average, nectarines and peaches stored at 4°C developed woolliness, and were judged less firm, sour and aromatic than those stored at 0°C. LeM nectarines stored at 0°C were judged firmer, more juicy, sweet, sour and aromatic, and less woolly than MoM fruit stored at 0°C and LeM and MoM nectarines stored at 4°C (Fig. 2, left), in contrast with the findings reported by Vanoli et al. (2008a and 2010). On the contrary, the sensory profiles of 'Spring Belle' peaches (Fig. 2, right) showed that LeM fruit stored at 0°C were firmer and sourer and less juicy and aromatic than MoM fruit stored at both temperatures and that LeM peaches stored at 4°C had the highest scores for woolliness. The opposite behavior of TRS maturity class in nectarines and in peaches with respect to the sensory attributes could be due to the different development of woolliness, a physiological disorder characterized by a coarse texture associated to a dry appearance. In this work, woolly fruit were also the less juicy, making the perception of the sensory attributes related to taste and flavor difficult.

Pears

ANOVA analysis underlined that storage atmosphere significantly influenced firmness, juiciness and sweetness (Table 4): NA pears were judged firmer, less juicy and sweet than those stored in CA and in DCA, while CA fruit were perceived firmer and as juicy and sweet as the DCA ones. In a previous work, Eccher Zerbini et al. (2005a) found that after 3 months of storage, 'Abbé Fétel' pears stored in NA softened with a firm and grainy texture and a watery taste, while CA pears retained better their quality. TRS maturity class significantly affected both the attributes related to texture (firmness and graininess) and the descriptors related to flavor (sweetness, sourness and aromatic), with LeM pears showing the lower scores for all these attributes. The comparison of sensory profiles (Fig. 3) underlines that MoM pears stored in CA and in DCA showed high juiciness, sweetness, sourness, astringency and low graininess, and were perceived as more aromatic than the other samples. LeM fruit stored in DCA had similar scores for juicy, grainy and sweet attributes, but were judged as less sour, aromatic and astringent than CA- and DCA-MoM ones. On the contrary, NA-MoM pears showed the highest scores for firmness, graininess and the lowest for juiciness comparing with the other samples, while the NA-LeM ones were the least sweet and sour. These results indicate that 'Abbé Fétel' pears classified at harvest as MoM have to be stored in CA and in DCA, as in NA they developed the worst sensory characteristics.

CONCLUSIONS

Our results indicate that, for all the species, besides the influence of storage conditions, there was also a great influence of TRS maturity classification at harvest. As expected, the sensory profiles were significantly affected by storage atmospheres and temperatures. CA apples were judged firmer, more crispy and juicy and less mealy than the NA ones, showing the sensory profiles proper of less ripe apples. Nectarines and peaches stored at 4°C were judged less firm, sour and aromatic than those stored at 0°C. 'Abbé Fétel' pears stored in NA developed the sensory profiles characteristic for this cultivar after long storage in air, i.e. they were firm, with dry and grainy pulp, in contrast with the sensory profiles of CA and DCA fruits, characterized by soft and juicy pulp. TRS maturity classification significantly influenced the sensory characteristics as fruit assigned to LeM or MoM classes at harvest developed specific sensory profiles after storage and shelf life. Apples and pears classified as MoM at harvest and stored in NA can easily develop physiological disorders such as mealiness and graininess; the same was true for MoM nectarines stored both at 0°C and 4°C which can become woolly. On the contrary, apples and pears classified as MoM at harvest but stored in CA and DCA showed well balanced sensory characteristics as these fruit after storage became soft, juicy, sweet, but sour enough. MoM 'Spring Belle' peaches stored at 0°C showed the best sensory profile and the LeM ones stored at 4°C the worst. On the contrary, LeM 'Morsiani90' nectarines stored at 0°C developed the best sensory characteristics, while no great differences were found between MoM nectarines stored at 0°C and those stored at 4°C whatever the TRS maturity class.

In conclusion TRS maturity classification at harvest can give some indications on the best storage conditions in order to obtain fruit with sensory characteristics that can satisfy the consumer.

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Tables

Table 1. 'Jonagored' apples: ANOVA analysis (top) and mean scores for the main effects (bottom). Significance of *F* ratio: *** P≤0.001%, **P≤0.01%, *P≤0.05%, ns, not significant. Factors: A, harvest; B, storage atmosphere; C, TRS maturity class.

	firm	crispy	mealy	juicy	sweet	sour	aromatic	pleasant
factors				*Main effects*				
A	***	***	*	ns	ns	***	ns	**
B	***	***	***	***	ns	***	ns	***
C	***	**	**	***	***	***	ns	ns
				Interaction				
A × B	*	ns	**	**	ns	ns	ns	ns
A × C	ns	ns	ns	ns	ns	ns	ns	ns
B × C	**	*	ns	ns	ns	ns	ns	ns
A × B × C	*	ns	ns	ns	ns	ns	ns	ns
means				*Harvest time*				
H1	53.9	52.8	48.5	50.6	47.8	55.1	51.6	53.3
H2	46.1	47.2	51.5	49.3	52.1	44.9	48.3	46.5
				Storage atmosphere				
CA	60.1	60.3	38.6	56.8	52.0	56.4	51.3	56.7
NA	39.9	39.7	61.4	43.1	48.0	43.5	48.7	43.1
				TRS maturity class				
LeM	54.5	54.3	46.3	53.5	44.8	55.1	49.2	51.7
MoM	45.5	45.7	53.7	46.5	55.2	44.9	50.7	48.1

Table 2. 'Morsiani90' late-maturing nectarines: ANOVA analysis (top) and mean scores for the main effects (bottom). Significance of *F* ratio: see Table 1. Factors: A, storage temperature; B, TRS maturity class.

	firm	juicy	woolly	sweet	sour	aromatic	pleasant
factors				*Main effects*			
A	***	ns	ns	ns	***	*	*
B	*	ns	ns	ns	*	*	**
				Interaction			
A × B	ns	ns	ns	ns	ns	ns	ns
means				*Storage temperature*			
0°C	50.6	44.1	51.0	45.4	55.8	53.4	47.8
4°C	33.7	39.5	61.4	39.8	36.8	39.1	36.5
				TRS maturity class			
LeM	47.3	47.0	50.5	44.9	52.5	51.9	48.3
MoM	37.0	36.6	61.9	40.3	40.1	40.6	35.9

Table 3. ‘Spring Belle’ early-maturing peaches: ANOVA analysis (top) and mean scores for the main effects (bottom). Significance of *F* ratio: see Table 1. Factors: A, storage temperature; B, TRS maturity class.

	firm	juicy	woolly	sweet	sour	aromatic	pleasant
factors				*Main effects*			
A	**	ns	*	ns	ns	ns	ns
B	***	***	ns	ns	ns	ns	*
				Interaction			
A × B	ns	ns	ns	ns	ns	ns	ns
means				*Storage temperature*			
0°C	50.9	51.3	49.0	52.2	52.4	52.9	52.2
4°C	44.5	53.1	58.1	55.5	45.6	51.3	49.9
				TRS maturity class			
LeM	53.7	46.5	56.8	50.2	52.5	50.9	46.6
MoM	41.7	58.0	50.3	57.6	45.5	53.1	55.5

Table 4. ‘Abbé Fétel’ pears: ANOVA analysis (top) and mean scores for the main effects (bottom). Significance of *F* ratio: see Table 1. Factors: A, storage atmosphere; B, TRS maturity class.

	firm	juicy	grainy	sweet	sour	aromatic	astringent	pleasant
factors				*Main effects*				
A	***	**	ns	*	ns	ns	ns	ns
B	*	ns	*	*	***	*	ns	ns
				Interaction				
A × B	ns	ns	ns	ns	ns	ns	ns	ns
means				*Storage atmosphere*				
CA	58.4 b	64.1 a	55.9	62.9 ab	63.1	64.2	61.4	63.3
NA	67.2 a	56.0 b	61.9	57.7 b	56.6	58.2	60.4	57.7
DCA	47.5 c	65.5 a	56.2	65.8 a	60.9	62.2	56.6	63.1
				TRS maturity class				
LeM	55.4	63.4	54.9	59.3	55.0	58.2	57.9	58.9
MoM	60.0	61.0	61.3	64.8	65.4	64.9	61.0	63.8

Figures

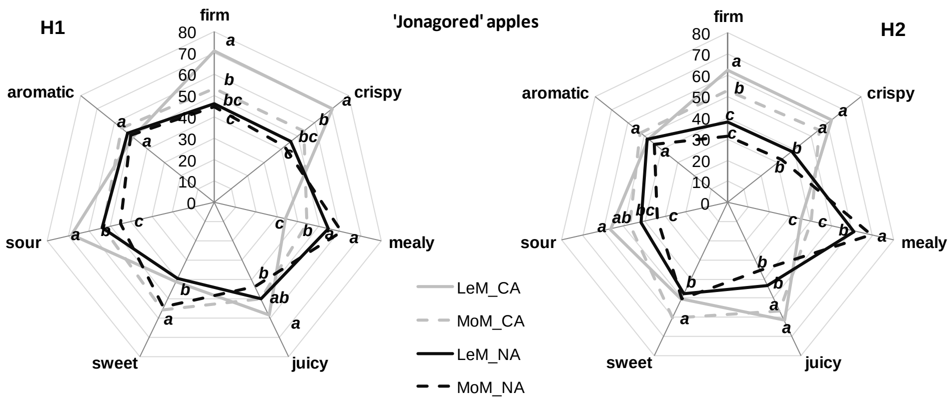


Fig. 1. Sensory profiles of H1 (left) and H2 (right) ‘Jonagored’ apples after 5 months’

storage in normal (NA) and controlled (CA) atmospheres in function of TRS maturity class.

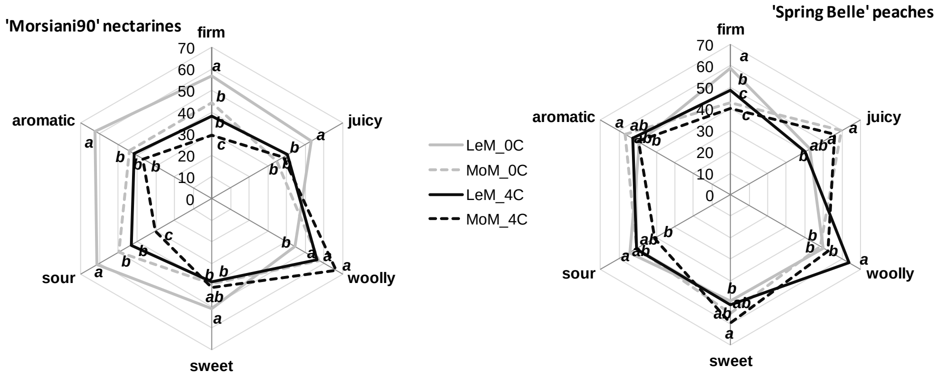
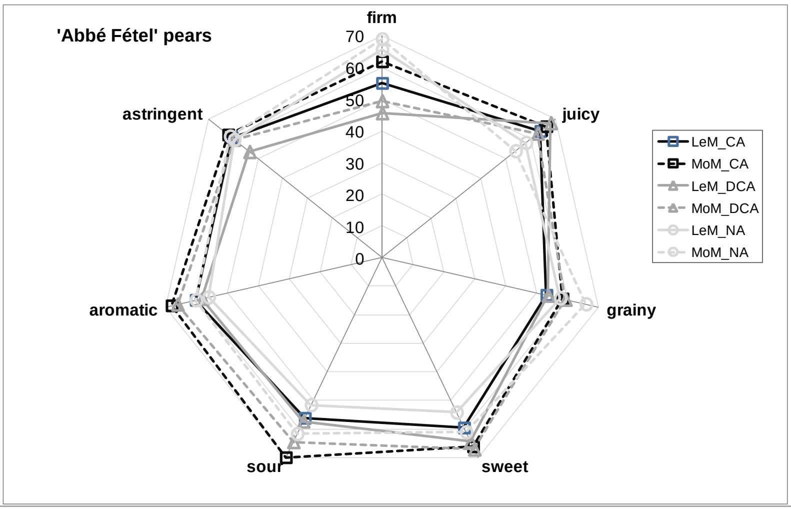


Fig. 2. Sensory profiles of 'Morsiani90' nectarines (left) and 'Spring Belle' peaches (right) after 1 month' storage in air at 0°C and 4°C and 5 (nectarines)/3 (peaches) days of shelf life at 20°C in function of TRS maturity class



	LeM_CA	MoM_CA	LeM_DCA	MoM_DCA	LeM_NA	MoM_NA
firm	**bc**	**ab**	**c**	**c**	**a**	**a**
juicy	**ab**	**a**	**a**	**ab**	**ab**	**b**
grainy	**b**	**b**	**b**	**b**	**b**	**a**
sweet	**ab**	**a**	**ab**	**a**	**b**	**ab**
sour	**bc**	**a**	**bc**	**ab**	**c**	**abc**
aromatic	**b**	**a**	**b**	**a**	**b**	**b**
astringent	**a**	**a**	**b**	**a**	**a**	**a**

Fig 3. Sensory profiles of 'Abbé Fétel' pears after 3 months' storage in normal (NA), controlled (CA) and dynamically controlled (DCA) atmospheres and 4 days of shelf life at 20°C in function of TRS maturity class