EFFECT OF INTER- AND INTRA-FRUIT VARIABILITY IN PREDICTING SOFTENING OF NECTARINES

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A B S T R A C T

In the new peach and nectarine cultivars the background colour is masked by blush, preventing the identification of the maturity stage. In previous trials with nectarines, fruit maturity was individually assessed by a new non-destructive technique, time-resolved reflectance spectroscopy (TRS), using the absorption coefficient at 670 nm (μ_a) measured at harvest on two opposite sides and averaged. In two nectarine cultivars (‘Ambra’ and ‘Spring Bright’), fruit softening during shelf life followed a logistic model in function of μ_a and of time at 20°C. Fruit firmness was measured by punch test (plunger 8 mm diameter) on two opposite fruit sides and averaged per fruit. The aim of this research was to compare the logistic model, where the mean fruit values of μ_a and of firmness were used, to the model fitted with the single corresponding values of μ_a and of firmness, measured on the same fruit side, in nectarines cv ‘Ambra’. The latter had R^2 lower than the former, showing that intra-fruit variability in firmness was not correlated to that in μ_a. In conclusion, mean fruit μ_a is better than single measurements for predicting nectarine fruit firmness during shelf life, provided that firmness is measured as mean of two fruit sides.

Key words: modelling, maturity, variability, firmness, quality, nectarine, time-resolved reflectance spectroscopy

INTRODUCTION

Variability is high between fruit. One of the main sources of variability is biological age. Peaches and nectarines do not mature at the same time on the tree, so they have to be harvested several times according to a maturity index such as background color. However, in new cultivars, the background color is masked by blush, which prevents the identification of the maturity stage.

A new non-destructive technique, time-resolved reflectance spectroscopy (TRS), can separately measure optical properties (absorption and scattering coefficients) at selected wavelengths in diffusive media (Cubeddu et al., 2001). In previous trials with nectarines, the absorption coefficient at 670 nm (μ_a), near the peak of absorption for chlorophyll, measured by TRS on two opposite fruit sides and averaged per fruit, was used to evaluate nectarine fruit maturity at harvest (Eccher Zerbini et al., 2003; 2004). It allowed to create sets of fruit samples comparable in maturity and then to follow softening in fruits of the same maturity. Fruit firmness was measured at different times during shelf life at 20°C on different batches of fruit representing the whole range of μ_a. Firmness was measured by the punch test (8 mm diameter) on two opposite sides of the peeled fruit and was averaged for each fruit. In ‘Spring Bright’ and ‘Ambra’ nectarine cultivars, fruit softening was modelled by non linear regression analysis, in function of μ_a and of time at 20°C (Eccher Zerbini et al., 2006). Fruit softening followed a logistic model (Equation 1): where F_{max} and F_{min} are maximum and minimum firmness, α is a constant, and $\beta_{\mu a}$ and β_{h20} are the coefficients for the independent variables μ_a (absorption coefficient at 670 nm measured at harvest) and h_{20} (hours at 20°C),

$$F = F_{min} + \frac{\left(F_{max} - F_{min}\right)}{1 + \exp\left(\alpha + \beta_{\mu_a} \cdot \mu_a + \beta_{h_{20}} \cdot h_{20}\right)}$$

respectively. The R^2 for the model was 0.85 for ‘Spring Bright’ and 0.75 for ‘Ambra’. For ‘Spring Bright’, the softening trend was similar both years, despite very different climatic conditions. The μ_a, accounting for 13% to 34% of total variability, can be considered as a measure of biological age. Variability is also present within a fruit. Fruit are not homogeneous, as μ_a and firmness are different in different places. The aim of this research was to compare the logistic model described above, where the mean fruit values of μ_a and of firmness were used, to the model fitted with the single localized data (corresponding values of μ_a and of firmness, measured on the same fruit side) in nectarines of the cultivar ‘Ambra’.

MATERIAL AND METHODS

Fruits were picked on July 5, 2004, and sorted by size (A = 73-79.9 mm, B=67-72.9 mm diameter) (Eccher Zerbini et al., 2006). At harvest, 180 fruits per size were measured on two sides by TRS (side 1 = redder; side 2 = less red; side 1 was marked by a felt pen) and ranked by decreasing absorption coefficient at 670 nm (μ_a) averaged per fruit, that is, from less mature to more mature fruit. The ranked fruits were grouped by 6, forming 30 groups corresponding to 30 levels of μ_a. Each fruit from each group was randomly assigned to a different time of analysis, so that each time, fruit from the whole range of μ_a could be analyzed. Fruit were analyzed after 20, 26, 45, 69, 93 and 117 hours at 20°C. Firmness was measured by punch testing (8 mm diameter) on peeled fruit in places corresponding to the two μ_a readings.

Single μ_a and firmness data of each fruit side were analyzed by correlation, by analysis of variance considering fruit and side as sources of variation, and by non-linear regression fitting model of equation (1) (SAS/STAT, SAS Institute Inc., Cary, NC, 1999).

RESULTS

Table 1. Analysis of variance for μ_a and firmness

		F			
Source	df	μ_a		Firmness	
Fruit	359	4.4	***	7.7	***
Side	1	24.8	***	2.6	n.s.
Error	359				

Table 2. Means and standard deviation of μ_a and firmness measured on two sides

	μ_a (cm^{-1})		Firmness (N)	
Side	mean	st.dev.	mean	st.dev.
1	0.096	0.032	16.5	18.0
2	0.103	0.036	17.5	18.5

All fruits were covered with intense blush. Measurements on the two sides were correlated, but with high variability (Fig. 1). Side 2 showed higher values of both μ_a and firmness on the average, but the difference was not significant for firmness (Tab. 1 and 2). In fact, in many fruits the difference between the sides was reversed. The mean difference between the

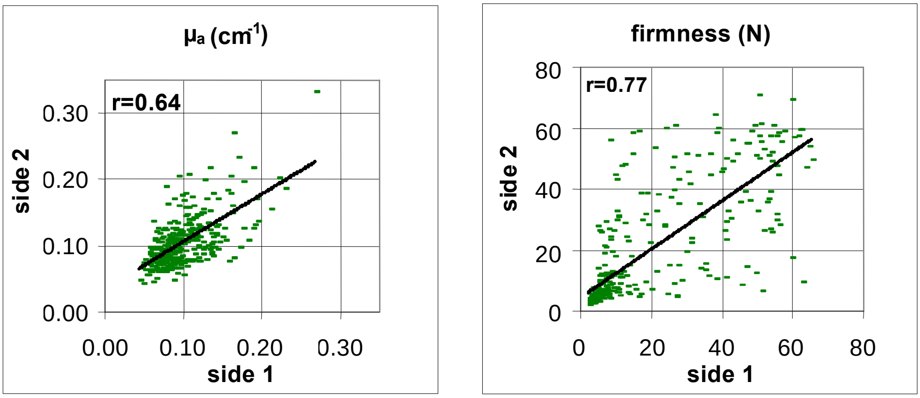

Figure 1. Correlation between measurements on the two sides

measurements on the two sides (side 2 – side 1) in function of the mean values grouped in classes is shown in Fig. 2. High mean fruit values of μ_a and intermediate values of firmness showed the highest variability of the difference between sides (Fig. 2). With the single data, total variability was increased, even though there were twice as many observations. Data collected after 20 hours are shown as an example in Fig. 3. The parameters estimated by the model with all the single data were not significantly different from those obtained with the mean values, but the adjusted R^2 was 0.66, compared to R^2 = 75 obtained with mean values. The same results were obtained using the data of only one side, side 1 or side 2 (Tab. 3). If single side values of firmness were modelled on mean fruit values of μ_a, R^2 did not increase, while if mean fruit firmness was modelled on single side values of μ_a, R^2 increased to 0.68 and 0.70 (Tab. 4). With all models, the parameters were similar, and not significantly different.

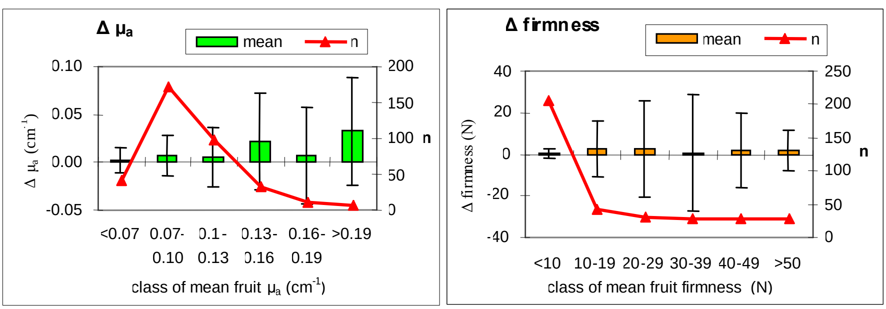

Figure 2. Differences between values measured on 2 fruit sides (side 2 - side 1) for μ_a (left) and firmness (right): bars are standard deviations, n is number of fruit in each class

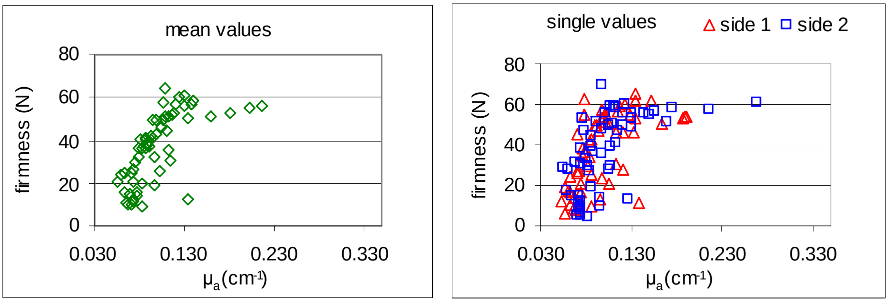

Figure 3. Firmness during shelf life in function of μ_a measured after 20 hours at 20°C. Mean fruit values (left) and single values on two fruit sides (right)

Table 3. Parameters (Est.) and approximate standard errors (s.e.) estimated for the logistic model in equation (1), considering single corresponding values of firmness and μ_a. F_{min}: minimum firmness; F_{max}: maximum firmness; βs are coefficients of independent variables (μ_a: coefficient of absorption at 670 nm measured at harvest; h_{20}: hours at 20°C)

	All single values n=720		Only side 1 n=360		Only side 2 n=360	
Parameter	Est.	s.e.	Est.	s.e.	Est.	s.e.
F_{min} (N)	3.9	0.7	4.2	1.0	3.7	1.1
F_{max} (N)	57	3	56	3	58	4
$\beta_{\mu a}$ (cm)	-37	4	-41	6	-34	5
β_{h20} (h^{-1})	0.065	0.006	0.072	0.010	0.060	0.009
α	1.9	0.2	2.0	0.3	1.9	0.3
Adj. R^2	*0.66*		*0.66*		*0.65*	

Table 4. Parameters (Est.) and approximate standard errors (s.e.) estimated for the logistic model in equation (1). Dependent variable is firmness as mean fruit or single side values, in relation to single side or mean fruit value of μ_a respectively. For names of parameters see Table 3. n = 360

Dep. Var.	Mean fruit firmness				Firmness side 1		Firmness side 2	
	μ_a side 1		μ_a side 2		mean fruit μ_a		mean fruit μ_a	
Parameter	Est.	s.e	Est.	s.e	Est.	s.e	Est.	s.e
F_{min} (N)	4.1	0.9	3.8	1.0	3.9	1.0	3.6	1.1
F_{max} (N)	56	3	55	4	53	3	58	4
$\beta_{\mu a}$ (cm)	-36	5	-31	4	-48	7	-42	6
β_{h20} (h^{-1})	0.066	0.008	0.061	0.008	0.071	0.010	0.061	0.008
α	1.6	0.3	1.5	0.3	2.7	0.4	2.4	0.3
Adj. R^2	*0.70*		*0.68*		*0.65*		*0.67*	

DISCUSSION

The variability in μ_a within fruit is not correlated to the variability in firmness. By using single data, the intra-fruit variability is added to the inter-fruit variability.

The results can be used to check if, in order to predict firmness during shelf life on the basis of maturity at harvest, it would be possible to measure fruit only on one side: with firmness measured only on one side, then it would not be different to use one single or two averaged measurements of μ_a, but the predictive power would be very low. A remarkable improvement is obtained if firmness is modelled as the mean fruit value, even with only one measurement of μ_a, and still more with the mean fruit value of μ_a. The importance of estimating fruit quality by the mean of measurements in different positions is confirmed, and this is especially true for firmness measurement.

In conclusion, mean fruit μ_a is better than single measurements for predicting nectarine fruit firmness during shelf life, provided that firmness is measured as the mean of both sides of the fruit.

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REFERENCES

Cubeddu R., D'Andrea C., Pifferi A., Taroni P., Torricelli A., Valentini G., Dover C., Johnson D., Ruiz-Altisent M., Valero C. 2001. Non-destructive quantification of chemical and physical properties of fruits by time-resolved reflectance spectroscopy in the wavelength range 650-1000 nm. APPL. OPT. 40: 538-543.

Eccher Zerbini P., Grassi M., Fibiani M., Rizzolo A., Biscotti G., Pifferi A., Torricelli A., Cubeddu R. 2003. Selection of 'Springbright' nectarines by time-resolved reflectance spectroscopy (TRS) to predict fruit quality in the marketing chain. ACTA HORT. 604: 171-177.

Eccher Zerbini P., Vanoli M., Grassi M., Rizzolo A., Fibiani M., Biscotti G., Pifferi A., Torricelli A., Cubeddu R. 2004. Time-resolved reflectance spectroscopy measurements as a non destructive tool to assess the maturity at harvest and to model the softening of nectarines. ACTA HORT. 682: 1459-1464.

Eccher Zerbini P., Vanoli M., Grassi M., Rizzolo A., Fibiani M., Cubeddu R., Pifferi A., Spinelli L., Torricelli A. 2006. A model for the softening of nectarines based on sorting fruit at harvest by time-resolved reflectance spectroscopy. POSTHARVEST BIOL. TECHNOL. 39: 223-232.

WPŁYW ZMIENNOŚCI WEWNĄTRZ OWOCÓW I POMIĘDZY NIMI NA PRZEWIDYWANIE MIĘKNIĘCIA NEKTARYN

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STRESZCZENIE

U nowych odmian brzoskwiń i nektaryn kolor zasadniczy skórki jest maskowany przez rumieniec, co utrudnia rozpoznanie stadium ich dojrzałości. We wcześniejszych doświadczeniach z nektarynami dojrzałość owoców podczas zbioru była określana indywidualnie z użyciem nowej niedestrukcyjnej techniki, spektroskopii fali odbitej w funkcji czasu (TRS), wykorzystując współczynnik absorpcji przy 670 nm (μ_a) mierzony po dwu przeciwnych stronach owocu, który był uśredniany. U dwu odmian nektaryn (‘Ambra’ i ‘Spring Bright’), mięknięcie owoców podczas obrotu towarowego wykazywało zgodność z modelem obliczeniowym w funkcji μ_a i czasu w temperaturze 20°C. Jędrność owoców była mierzona penetrometrem (trzpień o średnicy 8 mm) po dwóch przeciwnych stronach owocu i uśredniana dla każdego owocu. Celem prezentowanej pracy było porównanie modelu obliczeniowego, wykorzystującego średnie wartości μ_a i jędrności dla owocu, z modelem wykorzystującym pojedyncze wartości μ_a i jędrności mierzone po tej samej stronie owocu u nektaryn odmiany ‘Ambra’. Drugi model miał niższą wartość współczynnika korelacji R^2 niż pierwszy, wskazując, że wewnętrzna zmienność jędrności nie była skorelowana ze zmiennością współczynnika absorpcji μ_a. Podsumowując, dla przewidywania zmian jędrności nektaryn podczas obrotu towarowego wartości średnie współczynnika μ_a dla owoców są lepsze niż pomiary pojedyncze, pod warunkiem, że jędrność jest określana jako wartość średnia z pomiarów dla dwóch stron owocu.

Słowa kluczowe: modelowanie, dojrzałość, zmienność, jędrność, jakość, nektaryny, spektroskopia fali odbitej w funkcji czasu