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Pear quality characteristics by Vis / NIR spectroscopy

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ABSTRACT

Recently, non-destructive techniques such as the Vis / NIR spectroscopy have been used to evaluate the characteristics of maturation and quality of pears. The study aims to validate the readings by the Vis / NIR spectroscopy as a non-destructive way to assess the qualitative characteristics of pear cultivars 'Williams', 'Packams' and 'Carrick', produced according to Brazilian conditions. The experiment was conducted at the Pelotas Federal University, UFPel, in Pelotas / RS, and the instrument used to measure the fruit quality in a non-destructive way was the NIR- Case spectrophotometer (SACMI, Imola, Italy). To determine pears´ soluble solids (SS) and pulp firmness (PF), it was established calibration equations for each variety studied, done from the evaluations obtained by a non-destructive method (NIR-Case) and a destructive method. Further on, it was tested the performance of these readings by linear regressions. The results were significant for the soluble solids parameter obtained by the Vis / NIR spectroscopy; however, it did not achieve satisfactory results for the pear pulp firmness of these cultivars. It is concluded that the Vis / NIR spectroscopy, using linear regression, allows providing reliable estimates of pears´ quality levels, especially for soluble solids.

Key words: calibration, firmness, pear, soluble solids, validation.

INTRODUCTION

The decision of the consumer to purchase a fruit is usually based on the color and the ripening stages that are related to its sweetness and firmness. The content of soluble solids (SS) and firmness (PF) are important characteristics that determine, in a large scale, the perception of pear quality by the consumer. However, the determination of these characteristics is still performed in a destructive manner (Liu et al. 2008). This method of analysis requires the destruction of the fruits and a limited number of samples, therefore not providing all the information needed to identify the precise stage of maturation. Besides, these analysis do not provide all necessary information for quality control, especially when considering the individual evaluation of the fruit (Costa et al. 2006, Noferini et al. 2008).

Recently, non-destructive techniques such as the Vis / NIR spectroscopy, which provides quickly and accurately information for a wide range of cultivars, has been used to pre-define the maturation and fruit quality, as seen in researches done by several authors like Guyer and Yang (2000), Schaare and Fraser (2000), Costa et al. (2002), Fraser et al. (2003), Carlomagno et al. (2004), Clark et al. (2004),

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Saranwong et al. (2004), Han et al. (2006), Fu et al. (2007), Shao et al. (2007), Nicolai et al. (2007), Harker et al. (2008), Sinelli et al. (2008), Fan et al. (2009), Pérez-Marín et al. (2009), Xie et al. (2009), Valente et al. (2009), Cynkar et al. (2009), Camps and Christen (2009) and Kavdir et al. (2009).

The Vis / NIR spectroscopy has as an advantage, the possibility of determining, simultaneously, more than one quality characteristic, increasing the number of samples measurements and repeating the analysis of the same samples, by monitoring physiological changes in the fruit during the ripening process (Nicolai et al. 2007, Gabioud et al. 2008).

The spectroscopic data on the fruit internal quality are obtained by evaluating the absorption of Vis/ NIR light by functional groups at a specific wavelength (Banwell 1983). The procedure is to obtain a series of calibration samples and to evaluate the spectral data, as well as the quality characteristics of interest, which is determined by a reference method (usually destructive) (Peirs et al. 2003).

The Vis / NIR spectroscopy with wavelengths between 750 and 2500 nm has been used as a non-destructive method to determine the properties of organics products (Huang et al. 2007), and it has been successfully implemented for various fruits such as apples (Liu et al. 2007), peaches (Ying et al. 2005), kiwifruit (McGlone et al. 2002a) and mangoes (Schmilovitch et al. 2000). According to Liu et al. (2008), no information was found about models of validation for the Vis / NIR spectroscopy for soluble solids and firmness of intact pears. Furthermore, the wavelengths of 750-2500 nm are easily transmitted through the pear fruit; however, it is possible that other wavelengths successfully allow extracting information. In the present study, the Vis / NIR spectroscopy with a wavelength of 600-1000nm was used.

Therefore, the study aims to validate the readings by the Vis / NIR spectroscopy, as a non-destructive way to evaluate the pear quality of the cultivars 'Williams', 'Packams' and 'Carrick'.

MATERIALS AND METHODS

The experiment was conducted at the Laboratory of Fruticulture of Pelotas Federal University (UFPel) in Pelotas / RS, in February 2010 with 'Williams', 'Carrick' and 'Packams' pears from the Orchard of Palma Agricultural Center, at UFPel. The fruits were harvested at different stages of ripeness and from different locations, and stored in a cold chamber (0°C and 90% RH) for 30 days (each sample of the respective cultivars consisted of 40 fruits) for both the destructive evaluation by conventional methods, as well as the non-destructive evaluation to obtain the calibrations of different cultivars and to validate them.

The instrument used to determine the quality of fruits in a non-destructive way was the NIR-Case spectrophotometer (SACMI, Imola, Italy). This equipment performs the reading by transmittance. The light source consists of eight halogen lamp, and the wavelength varies between 600 and 1000nm. The readings were performed by the equipment considering the equatorial region of the fruit on opposite sides (A and B) of each pear for each cultivar determining the content of soluble solids (SS) and pulp firmness (FP) of the fruits.

To determinate the pears' SS and FP, first, calibration equations were settled for each variety studied from the evaluations by the non-destructive (NIR-Case) and destructive (reference method) methods. After obtaining the spectra from the existing equations for pears for the NIR-Case (SACM), evaluations of reference (destructive) were carried out separately considering the same sides of the fruits; evaluating the pulp firmness (PF) with a digital penetrometer with a tip diameter of 8mm (model 53 205, TR, Forli, Italy), removing the peel from both opposite sides of each fruit in the equatorial region, which the results were expressed in Newton (N); and it was also evaluated the solids soluble content (SS) with a digital refractometer (Atago PR32) in the same spots where the fruit firmness was analyzed and the

results expressed in °Brix. The spectra generated by NIR-Case and the values obtained by the method of reference of the samples were calculated using the NCS (NIR CALIBRATION SOFTWARE) Version 3.0 R C 1, resulting in new calibration equations for each cultivar. The correlations obtained by the spectra with the reference values of the quality characteristics for calibrations are performed by the software that comes with the equipment.

After obtaining the calibration equations for 'Williams', 'Packams' and 'Carrick' pears, the performance was tested (the validation). It was proceeded the validation of each equation for each cultivar obtained by the SACMI software for the NIR-Case spectrophotometer. It was used linear regressions to the values obtained through the NIR-Case and the reference method for the new samples. For this effect, it was utilized the Past program version 1.82b. The statistical parameters correlation coefficient (R), mean square error of predicted values (RMSEP) and the standard error of predicted values (SEP) were used to determine the accuracy of the calibration equations.

After the validation of the calibration equations for pears, experiments were designed consisting of pears cultivars 'Williams', 'Packams' and 'Carrick', on different rootstocks to determine the characteristics of quality using the best calibration equations obtained by the NIR-Case spectrophotometer. Spectral data were obtained through the NIR-Case to determine the characteristics of the quality of 'Williams', grafted on the Champion, Meliforme and Pyrus calleryana rootstocks, 'Packams' on the D'Angers, Smyrna, Alongado, Adam's and P. calleryana rootstocks, and 'Carrick' grafted on Portugal, MC, D'Vranje, BA 29 and Inta 267.

RESULTS AND DISCUSSIONS

The calibrations from the 'Williams', 'Packams' and 'Carrick' pears were obtained as a way of estimating accurate values of soluble solids (SS) and pulp firmness (PF), with the results being close to those obtained by the reference method. Table I presents the results of statistical parameters related to the calibrations, which were subjected to further validation in order to determine the respective quality characteristics of the pear cultivars according to the Brazilian conditions (Figs. 1, 2 and 3).

TABLE I
Statistical parameters related to the calibrations for soluble solids (SS) and pulp firmness (PF) of pears cultivars 'Williams', 'Packams' and 'Carrick' obtained with the NIR-Case. UFPel, 2010.

Cultivars	Statistical parameters		
	Characteristics	R	SEP
Williams	Soluble solids (SS)	0.96	0.25
	Pulp firmness (FP)	0.78	0.56
Packams	Soluble solids (SS)	0.92	0.30
	Pulp firmness (FP)	0.79	0.49
Carrick	Soluble solids (SS)	0.97	0.34
	Pulp firmness (FP)	0.78	0.59

Validation of the Calibrations to the Determination of Soluble Solids and Pulp Firmness of Pears

Soluble solids

The characterization of the values for soluble solids (SS) of pears that are used to validate the calibration of the cultivars evaluated and obtained by the SACMI software are presented in Table II. It is verified that the SS obtained for the validation of the calibration presented a variation between 9.60 and 12.90 ° Brix, 10.50 and 15.00 ° Brix and 10.80 and 16.20 ° Brix for 'Williams', 'Packams' and 'Carrick', respectively.

The largest gap between the minimum and maximum values of SS was obtained for 'Carrick' pears, which coincides with the ranges obtained by Nicolai et al. (2008) (10.4 and 15.4 ° Brix) for 'Conference' pears and by Liu et al. (2008) for 'Fengshi' pears (SS between 8.4 and 14.1 ° Brix). When comparing the values of minimum, maximum and

the average of both methods to determine SS (NIR-Case and reference), the values are relatively close. To 'Packams' cultivar, it was observed a difference of 0.93 for the average values of SS obtained from both methods (NIR-Case and reference), being higher when compared with the evaluated cultivars, mainly with the cultivar 'Carrick' that had the smallest difference (0.08). However, there seems to be a good correlation between the two methods for determining SS of the 'Packams' pears.

The results of the linear regressions for the values of the NIR-Case and of the soluble solids measured destructively (reference method) for the validation of the calibrations are shown in Figures 1, 2 and 3. It is observed that the coefficients allow to estimate the existence of a high correlation between the two methods for SS for 'Carrick' and 'Packams' pears (R = 0.82 and 0.80, respectively). These values were higher than those observed by Nicolai et al. (2008) who obtained an R of 0.77 for 'Conference' pears using the Vis/ NIR spectroscopy with a wavelength of 780-1700nm, and by Costa et al. (2002) who obtained an R = 0.71 for 'Abbé Fetel', 'Pass Crassane', 'Conference' and 'Comice' pears . However, these values were lower than the ones reported by Liu et al. (2008) who obtained a higher correlation coefficient (R = 0.91) for 'Fengshui' pears using a wavelength of 350-1800nm, and by Sun et al. (2009) who evaluated the use of Vis / NIR with a wavelength of 345-1040nm to determine SS for 'Cuiguan' pears, obtaining an R of 0.96 and an RMSEP of 0.53.

To validate the calibration equation for 'Williams', it was obtained an R of 0.60. Although this correlation coefficient between values obtained by both methods is lower (R = 0.60) than the coefficients obtained for 'Packams' and 'Carrick', and the R values for the respective cultivars evaluated in this study were within the obtained values by other authors. Tsai et al. (2007) and Ying and Liu (2008) worked with Japanese and Chinese pears and obtained correlation coefficients for SS between 0.60 and 0.85, and SEP between 0.40 and 0.62.

For the statistical parameters correlation coefficient (R), mean square error of predicted values (RMSEP) and standard error of predicted values (SEP), which were used to determine the accuracy of the calibration equations, it was observed the lowest value of RMSEP (0.34) for 'Carrick' and the highest value of RMSEP (4.17) for the cultivar 'Packams'. The SEP values obtained for the cultivars 'Williams', 'Packams' and 'Carrick' were 1.75, 4.06 and 0.33, respectively (Table III). The value of RMSEP (0.34) obtained in the validation of the calibration of the SS to 'Carrick' pears was less than the values obtained by Nicolai et al. (2008) who observed an RMSEP of 0.44 for 'Conference' pears with a wavelength between 780 and 1700nm, and by Liu et al. (2008) who obtained 0.66 for 'Fengshui' pears with a wavelength between 350 and 1800nm. Regarding the SEP values, Costa et al. (2002) had a SEP of 1.15 for the SS of pears, and Tsai et al. (2007) and Ying and Liu (2008), who worked with Japanese and Chinese pears, obtained a SEP between 0.40 and 0.62.

Regarding the RMSEP and SEP, ratings of 4.17 and 4.0, respectively, were observed for the cultivar 'Packams', in spite of a good correlation coefficient (R = 0.80), which could be due to the fruit sampling for the analysis of pears of the respective cultivar being more homogeneous. Delwiche and Norris (1993) concluded that incorporating heterogeneous samples in the calibration equation improves the classification accuracy of this equation, but it decreases the accuracy of the prediction of non-heterogeneous samples. Several authors, among them, Xiaobo et al. (2007), also studied the influence of regression models used and observed differences in the values of SEP and RMSEP for the SS.

Correlation coefficients relatively high and low RMSEP values indicate that non-destructive determinations by Vis / NIR can provide good estimates for pear quality parameters, especially for soluble solids (Liu et al. 2008). The correlation coefficients of the validation of the calibrations for the cultivars studied for SS coincide or are lower or

higher than those obtained for other fruits. Ventura et al. (1998), using NIR (811-999nm) for SS validation, obtained an R of 0.73 and 0.75 and a SEP of 1.05 for 'Golden Delicious' apple, and an R of 0.68 and 0.71 and a SEP from 1.06 to 1.11 for 'Jonagold' apples. McGlone et al. (2002b), using 500-1100nm, obtained an R of 0.79 and a SEP of 0.5 for Royal Gala apples. Liu et al. (2007) obtained an R of 0.84 and a SEP of 0.77 for 'Fuji apples'. For 'Sweet Lady' nectarines, using 1600-2400nm and 400-1700nm, the correlation coefficients were between 0.87 and 0.93 for SS (Pérez-Marín et al. 2009). Golic and Walsh (2006) obtained correlations of 0.88 for SS of pit fruits (peaches, nectarines and plums).

To validate the calibrations for the determination of the soluble solids content of pear cultivars 'Williams', 'Packams' and 'Carrick', it was obtained satisfactory correlation coefficients, being possible to accurately estimate the quality characteristic using the Vis / NIR spectroscopy with a wavelength of 600 -1000nm. McGlone and Kawano (1998) state that the wavelength between 800 and 1100nm is a good interval to estimate the content of soluble solids.

In general, it is suggested that the estimation of the SS by the NIR-Case is enhanced with new data, i.e., new calibration equations, in order to obtain a better precision in the estimation of the data. It is also suggested to increase the number of samples to be used for calibration with a larger range of values for the characteristic to be studied in order to increase the heterogeneity of the sample, and the greater the range, the better the consistency of the calibration. In the literature, the number of samples is quite variable, and it can be seen samples of 40 fruits (Gabioud et al. 2008), 80 fruits (Liu et al. 2008), 200 fruits (Costa et al. 2002), 340 fruits (Ventura et al. 1998) and 420 fruits (Nicolai et al. 2008).

Pulp firmness

For the values of the pear pulp firmness (PF), there was a range between 26.38 and 55.90 N for 'Williams', 31.48 and 71.39 N for 'Packams', and 35.01 and 62.47 N for 'Carrick'. The largest gap between the minimum and maximum values was observed for 'Packams', being this interval smaller than the range obtained by Nicolai et al. (2008) for 'Conference', with a range between 9.9 and 110.7 N for pulp firmness and considerably larger than the range observed by Liu et al. (2008) for 'Fengshi' (2.9 to 13.7 N). When comparing the average values for the firmness obtained by the reference method and the NIR-Case, it is observed that the values of the NIR-Case were lower, except for the cultivar 'Carrick', the others were smaller than those obtained by the reference method. The smallest difference between the mean values for the pulp firmness obtained by the two methods was observed for the cultivar 'Carrick' (difference of 0.12), and the highest difference was observed for 'Packams' (0.90) (Table II).

With respect to the linear regression between the values of firmness determined by the two methods for 'Williams', 'Packams' and 'Carrick' pears, correlation coefficients of R = 0.35, R = 0.26 and R = 0.12 were obtained, respectively (Figs. 1, 2 and 3). The obtained values of R are lower than the results observed by Nicolai et al. (2008) in 'Conference' pears with an R= 0.59, and the same authors consider these values of R unsatisfactory for determining the firmness by spectroscopic techniques. However, these results are very different from those obtained by Costa et al. (2002) who found an R = 0.71 in four pear cultivars (Abbé Fetel, Crassane Pass, Conference and Comice), and Liu et al. (2008), who obtained an R = 0.85 for 'Fengshui' pears with an interval of wavelength between 350 and 1800nm, found greater values that have been obtained in this study. For other fruits, authors such as Valero et al. (2004) obtained an R = 0.77 for kiwis. Gabioud et al. (2008), using NIR-Case (SACM), observed a correlation coefficient of 0.76 for apples firmness. Gómez et al. (2006), using a wavelength of 400-2350nm, observed a correlation of 0.69 to determine tangerines firmness.

Table III shows the statistical parameters concerning the validation of the calibrations for the determination of pear firmness. In which, it was obtained the lowest RMSEP for the 'Carrick' cultivar (RMSEP = 5.29 N). This value was lower than that observed by Nicolai et al. (2008) (RMSEP = 10.4 N) for pears, by 'McGlone' and 'Kawano' (1998) for kiwis (RMSEP = 7.0 N) and by Gómez et al. (2006) for tangerines (RMSEP = 8.53 N), and higher RMSEP = 1.23 N obtained by Liu et al. (2008). For 'Packmas' cultivars, an RMSEP = 34.48 N was obtained, which is a value considered relatively high for the determination of firmness. According to Peirs et al. (2002), the prediction standard errors (RMSEP and SEP) ranged between 8 and 12N; however, Lu and Peng (2006) obtained SEP values between 15 and 20N for peaches firmness using a wavelength between 500-1000nm. The value of SEP was also the lowest value in calibrations for pears firmness of 'Carrick' (SEP = 5.1 N), being this value lower than that obtained by Costa et al. (2002) (SEP of 8.82 N) for pears and by Lu et al. (2000) (SEP of 6.2 N) for 'Golden Delicious' apples and by Schmilovitch et al. (2000) for mangoes with SEP of 17.14 N.

For Liu et al. (2008), correlation coefficients relatively high and RMSEP and SEP with values considered low indicate that nondestructive determinations by Vis / NIR can provide good estimates for pear quality parameters. In this study, although the statistical parameters (RMSEP and SEP) for the validation of calibrations for the firmness of the respective cultivars are within the limit when compared to those obtained by other authors, the correlation coefficients (R) obtained showed low values. The cause to justify the low values of RMSEP and SEP (indicating a good estimate) even with low correlations may be due to the use of heterogeneous samples to obtain the calibrations and to validate them, which confirms the wide range of values obtained for the firmness of the fruits of different cultivars evaluated. According to Delwiche and Norris (1993), heterogeneous samples in the calibration equations improve the classification accuracy of this equation, but they decrease the accuracy of prediction of non-heterogeneous samples.

The weak correlations obtained for the pulp firmness of 'Williams', 'Packams' and 'Carrick' cultivars may be due to several factors such as the range of the wavelength used by the NIR-Case (between 600 and 1000nm) not being the most suitable for extracting information on the spectrum bands that are related to the pear firmness of these cultivars, as verified by Swierenga et al. (2000). Moreover, according to Harker et al. (1996), in the reference method used to determine the firmness by a penetrometer, the readings may vary according to the evaluator; in other words, the evaluator may influence the measurements performed by the equipment. Nicolai et al. (2006) suggests the use of non-destructive methods of impact or vibration to determine this trait.

According to Zerbini (2006), the Vis / NIR spectroscopy has been used to estimate quality characteristics such as soluble solids, firmness, dry matter and acidity. In general, the estimation of SS is satisfactory and consistent, while for the remaining properties, the results are quite variable. Nicolai et al. (2008) argues that the Vis / NIR spectroscopic techniques are not valid to estimate the firmness of pears.

In the regression methods used for data processing, two or more instrumental responses are related to the property of interest. These methods allow the analysis even with some interference, since they are present in the calibration samples (Brereton 2000). In this study, the linear regression method used for processing data for the validation of the calibration of pears cultivars provided significant results for the determination of SS by the Vis / NIR spectroscopy; however, no good results were obtained for pear firmness of these cultivars.

TABLE II
Characterization of fruit samples used to validate the calibration of pears cultivars 'Williams', 'Packams 'and 'Carrick'. UFPel, 2010.

Cultivars	Characteristics	Methods	Minimum	Maximum	Mean	Standard Deviation
Williams	SS (°Brix)	ND	10.02	13.59	11.94	0.91
		D	9.60	12.90	11.54	0.88
	PF (N)	ND	0.78	54.03	37.66	1.08
		D	26.38	55.90	42.36	0.77
Packams	SS (°Brix)	ND	10.15	13.73	11.76	0.89
		D	10.50	15.00	12.69	1.00
	PF (N)	ND	33.24	81.40	48.74	1.01
		D	31.48	71.39	56.58	0.91
Carrick	SS (°Brix)	ND	10.83	14.91	13.03	0.96
		D	10.8	16.2	13.11	1.39
	PF (N)	ND	44.91	67.18	52.66	0.50
		D	35.01	62.47	51.48	0.62

SS = Soluble solids; PF = Pulp firmness; ND = non-destructive, D = destructive.

TABLE III
Statistical parameters concerning the validation of the calibrations for the determination of soluble solids and pulp firmness of pears cultivars 'Williams', 'Packams' and 'Carrick'. UFPel, 2010.

Cultivars	Statistical parameters			
	Characteristics	R	RMSEP	SEP
Williams	Soluble solids	0.60	1.80	1.75
	Pulp firmness	0.35	2.11	2.05
Packams	Soluble solids	0.80	4.17	4.06
	Pulp firmness	0.26	3.48	3.39
Carrick	Soluble solids	0.82	0.34	0.33
	Pulp firmness	0.12	0.54	0.52

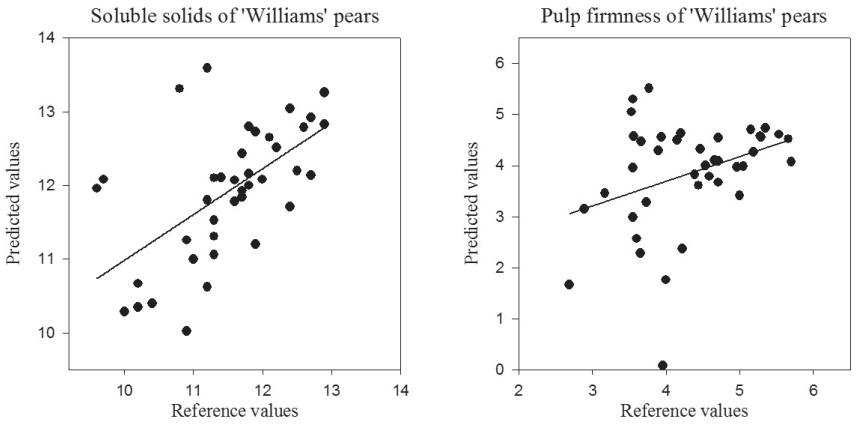

Figure 1. Relation between the values of soluble solids and pulp firmness estimated by NIR-Case and the values obtained for each characteristic by the destructive method (of reference) used to validate the calibration for 'Williams' pears. UFPel, 2010.

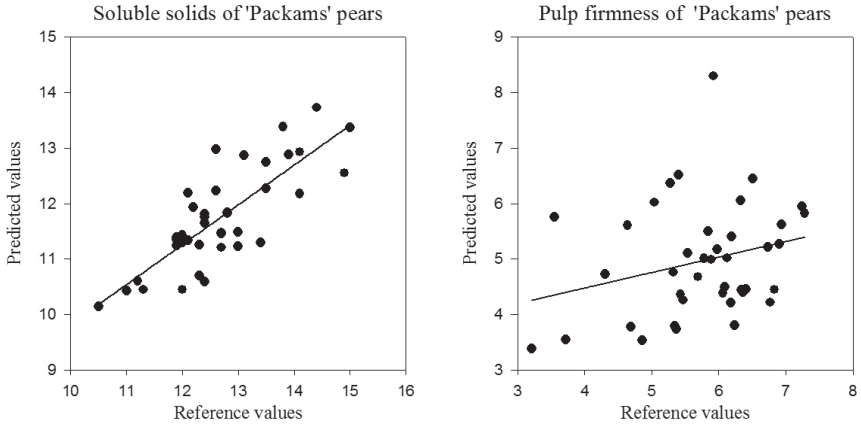

Figure 2. Relation between the values of soluble solids and pulp firmness estimated by NIR-Case and the values obtained for each characteristic by the destructive method (of reference) used to validate the calibration for 'Packams' pears. UFPel, 2010.

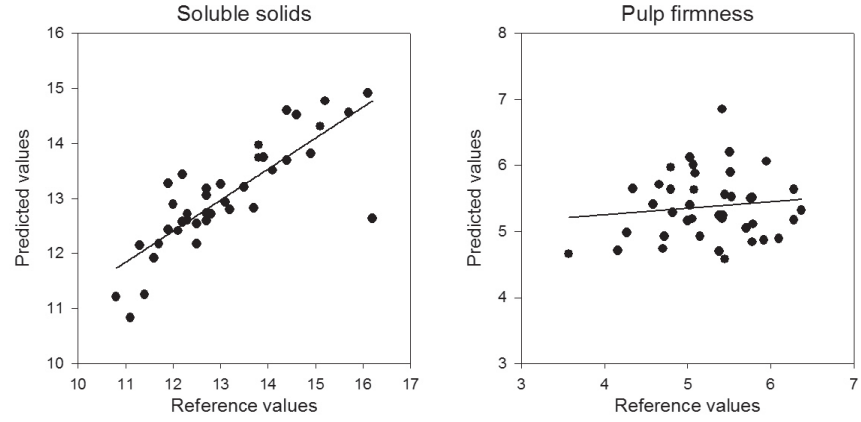

Figure 3. Relation between the values of soluble solids and pulp firmness estimated by NIR-Case and the values obtained for each characteristic by the destructive method (of reference) used to validate the calibration for 'Carrick' pears. UFPel, 2010.

DETERMINATION OF PEAR QUALITY CHARACTERISTICS BY VIS / NIR SPECTROSCOPY

Based on the results obtained in this study, to validate the calibration for determining the pear quality characteristics by the Vis / NIR spectroscopy to be satisfactory only for soluble solids, they were also tried in 'Williams', 'Packams' and 'Carrick' pears, grafted on different rootstocks using the best calibration.

Table IV presents the results of the descriptive statistics of the values of soluble solids content of 'Williams', 'Packams' and 'Carrick' pears on different rootstocks determined by the Vis / NIR spectroscopy using calibrations obtained by NIR-Case. And, as observed, the variation between the minimum and maximum values of SS for each cultivar grafted on different rootstocks has values close to those obtained by the reference method for the validation of the calibrations used for the determination of this quality characteristic. It can be observed that the averages for each cultivar are close to the averages in the validation. Thus, it is confirmed that the use of them determines the evolution of the ripe fruit and the most appropriate harvest time.

CONCLUSIONS

It can be concluded that it is possible to use a non-destructive method for the Vis / NIR spectroscopy to determine pear quality characteristics. With the use of linear regression, relations were established between spectral parameters obtained by the Vis / NIR spectroscopy and internal fruit quality, which make possible to provide reliable estimates of the quality indexes for pears, especially for soluble solids.

RESUMO

Recentemente, técnicas não destrutivas como a espectroscopia Vis/NIR têm sido utilizadas para avaliar as características de maturação e qualidade das peras. O trabalho tem como objetivo validar as leituras por espectroscopia Vis/NIR, como forma não destrutiva de avaliar as características qualitativas em peras das cultivares Williams, Packams e Carrick produzidas em condições

TABLE IV

Minimum, maximum, mean and standard deviation values of soluble solids (SS) of pears cultivars 'Williams', 'Packams' and 'Carrick', on different rootstocks determined by the Vis / NIR spectroscopy using calibrations obtained for the NIR-Case. UFPel, 2010.

Cultivars	Rootstocks	Minimum-Maximum SS (°Brix)	Mean	Overall mean	Standard Deviation
Williams	Champion	10.36 - 13.89	12.16	11.50	0.81
	Meliforme	8.91 - 13.64	11.67		1.03
	P.calleryana	9.38 - 12.15	10.68		0.92
Packams	D'angers	9.82 - 13.80	11.70	11.64	0.82
	Smyrna	7.67 - 15.73	10.48		1.62
	Alongado	11.50 - 16.15	13.26		1.09
	Adam's	10.66 - 15.05	12.35		1.00
	P.calleryana	8.41 - 12.12	10.43		0.62
Carrick	Portugal	10.81 - 16.19	13.67	13.02	1.16
	MC	11.35 - 16.18	13.82		1.08
	D'vranja	10.44 - 14.12	12.65		0.75
	BA29	9.87 - 14.79	12.51		1.14
	Inta 267	11.06 - 14.31	12.45		0.77

SS = Soluble solids.

brasileiras. O experimento foi realizado na Universidade Federal de Pelotas, UFPel, Pelotas/RS e o instrumento utilizado para determinar a qualidade dos frutos de forma não destrutiva foi o espectrofotômetro NIR-Case (SACMI, Imola, Itália). Para a determinação de sólidos solúveis (SS) e firmeza da polpa (FP) das peras, estabeleceu-se a calibração para cada cultivar em estudo a partir das avaliações obtidas pelo método não destrutivo (NIR-Case) e pelo método destrutivo e, posteriormente, testou-se o desempenho destas leituras através de regressões lineares. Os resultados foram significativos para o parâmetro sólidos solúveis obtido por espectroscopia Vis/NIR, no entanto, não se obteve resultados satisfatórios para a firmeza da polpa de peras dessas cultivares. Conclui-se que a espectroscopia Vis/NIR utilizando regressão linear possibilita fornecer estimativas seguras dos índices de qualidade para peras, especialmente para os sólidos solúveis.

Palavras-chave: calibração, firmeza, pereira, sólidos solúveis, validação.

REFERENCES

BANWELL CN. 1983. Fundamentals of molecular spectroscopy, 3rd ed., London: UK McGraw-Hill, 338 p.

BRERETON RG. 2000. Introduction to Multivariate Calibration in Analytical Chemistry. Analyst 125: 2125-2154.

CAMPS C AND CHRISTEN D. 2009. Non-destructive assessment of apricot fruit quality by portable visible-near infrared spectroscopy. Food Sci Technol-Leb 42: 1125-1131.

CARLOMAGNO G, CAPOZZO L, ATTOLICO G AND DISTANTE A. 2004. Non-destructive grading of peaches by near infrared spectrometry. Infrared Phys Techn 46: 23-29.

CLARK CJ, MCGLONE VA, DE SILVA HN, MANNING MA, BURDON J AND MOWAT AD. 2004. Prediction of storage disorders of kiwifruit (*Actinidia chinensis*) based on visible-NIR spectral characteristics at harvest. Postharvest Biol Tec 32: 147-158.

COSTA G, NOFERINI M AND ANDREOTTI C. 2002. Non-destructive determination of internal quality in intact pears by near infrared spectroscopy. In: INTERNATIONAL SYMPOSIUM ON PEAR, 8, Bologna Proceedings…, Bologna: Acta Hortic, p. 821-825.

COSTA G, NOFERINI M, FIORI G AND ZIOSI V. 2006. Internal fruit quality: how to influence it, how to define it. Acta Hortic 712: 339-346.

CYNKAR W, COZZOLINO D AND DAMBERGS RG. 2009. The effect of sample storage and homogenisation techniques on the chemical composition and near infrared spectra of white grapes. Food Res Int 42: 653-658.

DELWICHE SR AND NORRIS KH. 1993. Classification of Hard Red Wheat by Near-Infrared Diffuse Reflectance Spectroscopy. Cereal Chem 70: 29-35.

FAN G, ZHA J, DUB R AND GAO L. 2009. Determination of soluble solids and firmness of apples by Vis/NIR transmittance. J Food Eng 93: 416-420.

FRASER DG, JORDAN RB, KÜNNEMEYER R AND MCGLONE VA. 2003. Light distribution inside mandarin fruit during internal quality assessment by NIR spectroscopy. Postharvest Biol Tec 27: 185-196.

FU X, YING Y, LU H AND XU H. 2007. Comparison of diffuse reflectance and transmission mode of visible-near infrared spectroscopy for detecting brown heart of pear. J Food Eng 83: 317-323.

GABIOUD S, BAUMGARTNER D, GASSER F, KNEUBÜHLER Y, LATTMANN S AND HOHN E. 2008. Non destructive quality measurements on apples. Acta Hortic 796: 217-224.

GOLIC M AND WALSH KB. 2006. Robustness of calibration models based on near infrared spectroscopy for the in-line grading of stonefruit for total soluble solids content. Anal Chim Acta 555: 286-291.

GÓMEZ AH, HE Y AND PEREIRA AG. 2006. Non-destructive measurement of acidity, soluble solids and firmness of Satsuma mandarin using Vis/NIR-spectroscopy techniques. J Food Eng 77: 313-319.

GUYER D AND YANG X. 2000. Use of genetic artificial neural networks and spectral imaging for defect detection on cherries. Comput Electron Agr 29: 179-194.

HAN D, TU R, LU C, LIU X AND WEN Z. 2006. Nondestructive detection of brown core in the Chinese pear 'Yali' by transmission visible–NIR spectroscopy. Food Control 17: 604-608.

HARKER FR, KUPFERMAN EM, MARINC AB, GUNSON FA AND TRIGGS CM. 2008. Eating quality standards for apples based on consumer preferences. Postharvest Biol Tec 50: 70-78.

HARKER FR, MAINDONALD JH AND JACKSON PJ. 1996. Penetrometer measurement of apple and kiwifruit firmness: operator and instrument differences. J Am Soc Hortic Sci 121(5): 927-935.

HUANG Y, CAVINATO AG, TANG J, SWANSON BG, LIN M AND RASCO BA. 2007. Characterization of solegel transitions of food hydrocolloids with near infra-red spectroscopy. Food Sci Technol-Leb 40: 1018-1026.

KAVDIR I, BUYUKCAN MB, LU R, KOCABIYIK H AND SEKER M. 2009. Prediction of olive quality using FT-NIR spectroscopy in reflectance and transmittance modes. Biosyst Eng 103(3): 304-312.

LIU Y, CHEN X AND OUYANG A. 2008. Nondestructive determination of pear internal quality indices by visible and near-infrared spectrometry. Food Sci Technol-Leb 41: 1720-1725.

LIU Y, YING Y, FU X AND LU H. 2007. Experiments on predicting sugar content in apples by FT-NIR technique. J Food Eng 80: 986-989.

LU R, GUYER DE AND BEAUDRY RM. 2000. Determination of firmness and sugar content of apples using near-infrared diffuse reflectance. J Texture Stud 31: 615-630.

LU R AND PENG Y. 2006. Hyperspectral scattering for assessing peach fruit firmness. Biosyst Eng 93: 161-171.

MCGLONE VA, JORDAN RB AND MARTINSEN PJ. 2002b. Vis/NIR estimation at harvest of pre- and poststorage quality indices for 'Royal Gala' apple. Postharvest Biol, Tec 25: 135-144.

MCGLONE VA, JORDAN RB, SEELYE R AND MARTINSEN PJ. 2002a. Comparing density and NIR methods for measurement of Kiwifruit dry matter and soluble solids content. Postharvest Biol Tec 26: 191-198.

MCGLONE VA AND KAWANO S. 1998. Firmness, dry-matter and soluble-solids assessment of postharvest kiwifruit by NIR spectroscopy. Postharvest Biol Tec 13: 131–141.

NICOLAI BM, BEULLENS K, BOBELYN E, HERTOG MLATM, SCHENK A, VERMEIR S AND LAMMERTYN J. 2006. Systems to characterize internal quality of fruit and vegetables. In: INTERNATIONAL CONFERENCE ON MANAGING QUALITY IN CHAINS – THE INTEGRATED VIEW ON FRUITS AND VEGETABLES QUALITY, 4, Bangkok Proceedings…, Bangkok: Acta Hortic, p. 59-65.

NICOLAI BM, BEULLENS K, BOBELYN E, PEIRS A, SAEYS W, THERON KI AND LAMMERTYN J. 2007. Nondestructive measurement of fruit and vegetable quality by means of NIR spectroscopy: A review. Postharvest Biol Tec 46(2): 99-118.

NICOLAI BM, VERLINDEN BE, DESMET M, SAEVELS S, SAEYS W, THERON K, CUBEDDU R, PIFFERI A AND TORRICELLI A. 2008. Time-resolved and continuous wave NIR reflectance spectroscopy to predict soluble solids content and firmness of pear. Postharvest Biol Tec 47: 68-74.

NOFERINI M, FIORI G, ZIOSI V AND COSTA G. 2008. L'indice DA, un nuovo parametro non distruttivo per stabilire l'epoca di raccolta e la qualità del frutto di pesco. Frutticoltura 7-8: 26-29.

PEIRS A, SCHEERLINCK N, TOUCHANT K AND NICOLAI BM. 2002. Comparison of Fourier Transform and Dispersive Near-Infrared Reflectance Spectroscopy for Apple Quality Measurements. Biosyst Eng 81(3): 305-311.

PEIRS A, TIRRY J, VERLINDEN B, DARIUS P AND NICOLAI BM. 2003. Effect of biological variability on the robustness of NIR models for soluble solids content of apples. Postharvest Biol Tec 28(2): 269-280.

PÉREZ-MARÍN D, SÁNCHEZ MT, PAZ P, SORIANO MA, GUERRERO JE AND GARRIDO-VARO A. 2009. Non-destructive deter-mination of quality parameters in nectarines during on-tree ripening and postharvest storage. Postharvest Biol Tec 52: 180-188.

SARANWONG S, SORNSRIVICHAI J AND KAWANO S. 2004. Prediction of ripe-stage eating quality of mango fruit from its harvest quality measured nondestructively by near infrared spectroscopy. Postharvest Biol Tec 31: 137-145.

SCHAARE PN AND FRASER DG. 2000. Comparison of reflectance, interactance and transmission modes of visible-near infrared spectroscopy for measuring internal properties of kiwifruit (*Actinidia chinensis*). Postharvest Biol Tec 20: 175-184.

SCHMILOVITCH Z, MIZRACH A, HOFFMAN A, EGOZI H AND FUCHS Y. 2000. Determination of mango physiological indices by near-infrared spectrometry. Postharvest Biol Tec 19: 245-252.

SHAO Y, HE Y, GÓMEZ AH, PEREIR AG, QIU Z AND ZHANG Y. 2007. Visible/near infrared spectrometric technique for nondestructive assessment of tomato 'Heatwave' (*Lycopersicum esculentum*) quality characteristics. J Food Eng 81: 672-678.

SINELLI N, SPINARDI A, EGIDIO VD, MIGNANI I AND CASIRAGHI E. 2008. Evaluation of quality and nutraceutical content of blueberries (*Vaccinium corymbosum L.*) by near and mid-infrared spectroscopy. Postharvest Biol Tec 50: 31-36.

SUN T, LIN H, XU H AND YING Y. 2009. Effect of fruit moving speed on predicting soluble solids content of 'Cuiguan' pears (*Pomaceae pyrifolia* Nakai cv. Cuiguan) using PLS and LS-SVM regression. Postharvest Biol Tec 51: 86-90.

SWIERENGA H, WÜLFERT F, NOORD OE, WEIJER AP, SMILDE AK AND BUYDENS LMC. 2000. Development of robust calibration models in near infra-red spectrometric applications. Anal Chim Acta 411: 121-135.

TSAI CY, CHEN HJ, HSIEH JF AND SHENG CT. 2007. Fabrication of a near infrared online inspection system for pear fruit. Int Agric Eng J 16: 57-70.

VALENTE M, LEARDI R, SELF G, LUCIANO G AND PAIN JP. 2009. Multivariate calibration of mango firmness using vis/NIR spectroscopy and acoustic impulse method. J Food Eng 94: 7-13.

VALERO C, RUIZ-ALTISENT M, CUBEDDU R, PIFFERI A, TARONI P, TORRICELLI A, VALENTINI G, JOHNSON DS AND DOVER CJ. 2004. Detection of internal quality in kiwi with time-domain diffuse reflectance spectroscopy. Appl Eng Agric 20: 223-230.

VENTURA M, JAGER A, PUTTER H AND ROELOFS FPMM. 1998. Non-destructive determination of soluble solids in apple fruit by near infrared spectroscopy (NIRS). Postharvest Biol Tec 14: 21-27.

XIAOBO Z, JIEWEN Z, XINGYI H AND YANXIAO L. 2007. Use of FT-NIR spectrometry in non-invasive measurements of soluble solid contents (SSC) of 'Fuji' apple based on different PLS models. Chemometr Intell Lab 87: 43-51.

XIE L, YING Y AND YING T. 2009. Classification of tomatoes with different genotypes by visible and short-wave near-infrared spectroscopy with least-squares support vector machines and other chemometrics. J Food Eng 94: 34-39.

YING Y AND LIU Y. 2008. Nondestructive measurement of internal quality in pear using genetic algorithms and FT-NIR spectroscopy. J Food Eng 84: 206-213.

YING YB, LIU YD, WANG JP, FU XP AND LI YB. 2005. Fourier transform near infrared determination of total soluble solids and available acid in intact peaches. T Asae 48(1): 229-234.

ZERBINI PE. 2006. Emerging technologies for non-destructive quality evaluation of fruit. J Fruit Ornam Plant Res 14(2): 13-23.