Ripening changes determination in kiwi using NIR technology and the influence of the temperature in the measurements

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Introduction

Production of kiwifruit *(Actinidia deliciosa*) has undergone a significant development in the last years with an increasing international market. At present, the production in Spain is about 15000 tn and more than 35000 tn are imported from France, Italy and New Zeland.[1]

Kiwifruit is a climatic fruit and its maturation is linked with the rise in ethylene production and in the respiration rate. It can be stored for four to six months,[2] as near as to 0ºC as possible and under 90 to 95 percent relative humidity. All potential sources of ethylene contamination should be eliminated in the storage. For long-term storage, use of controlled atmospheres has been shown to be effective provided that both 0ºC and ethylene less than 50 ppb are maintained.[3]

Consumer satisfaction is achieved when ripe fruit reaches at least 12.5% soluble solids concentration. Fruit at 2–3 pounds-force flesh firmness is considered ripe. Prediction of ripe kiwifruit quality can be done by measuring total solids at harvest destructively and non-destructively (near infrared).[3]

Therefore, the use of fast and non-destructive methods for ripening control is desirable. In this sense, near infrared (NIR) spectroscopy technology has proved to be very useful.

NIR analysis has a good speed of response since it produces results in less than 60 seconds. With NIR, there is no traditional sample preparation, no need for dangerous reagents or solvents, eliminates the sampling errors common to other methods caused by manual sample handling and reagent contamination. Its advantages include low cost, and high repeatability and reproducibility levels.[4]

According to Talsky,[5] at low temperatures, the interchange of energy between neighbouring molecules is reduced. Absorption bands of some materials measured at liquid air temperature are sharpened to approximate more closely the absorption bands of a vapour. In addition to this phenomenon, the absorption-band intensity may be increased by cooling the specimen until it becomes embedded in a mass of microcystals of ice or other cooling medium. This is useful when observing weak bands. The increase in intensity is due to the larger path of the light passing through the absorbing media which is reflected multiply by the microcrystals.

The objectives of this work are: to evaluate the ripening changes in kiwifruits, to estimate the soluble solids content from NIR technology and to evaluate the influence of the temperature in the NIR measures.

Materials and methods

A sample of 30 Hayward kiwifruits were collected and stored for three months under cold conditions. The first day the NIR measures were done at three temperatures (0.5ºC, 10 ºC and 20ºC).

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Then, the kiwifruits were at 20ºC to perform the essays during five consecutive days. The refractometric index was determined at the end of the experiment (5th day).

The reflectance spectra in the near-infrared region between 800 and 2500 nm were taken with a Varian CARY 500 Scan spectrophotometer equipped with an integrated sphere to measure reflectance in solid samples. This measurement is then smoothed and expressed as log $1/R$.

Then we proceeded to determine the soluble solid content in each kiwi with an Ivymen DR-101 BRIX digital refractometer, obtaining the reference measurement required.

We will attempt to obtain a valid equation to predict the model for it we will establish a correlation between the spectral values expressed as log $1/R$ and the reference analysis (ºBrix: soluble solids content).

We have also introduced ripening degree variable in order to observe the NIR capacity to determinate little changes of maturation occurs during the five days of the essays.

The information has been analysed with SPSS and SAS statistical programmes, which include a wide range of rapid data-processing applications and procedures, with a large number of options and graphic representations. The tests performed for this study are discriminant analysis and multiple linear regression.

Discriminant analysis is a statistical technique to classify individuals or objects into mutually exclusive and exhaustive groups on the basis of a set of independent variables. When the dependent variable can place each individual or object, in one and only one of the a priori defined groups, and we have a set of independent variables, the objective is to discriminate between the respective groups, on the basis of the observed scores on the set of independent variables.

The objective of the multiple linear regression analysis is to use the independent variables with known values to predict the only dependent variable selected, obtaining a regression equation, also known as theoretical regression value. This equation is validated with the coefficient R^2 (coefficient of multiple determination); the closer it is to one, better is the prediction.

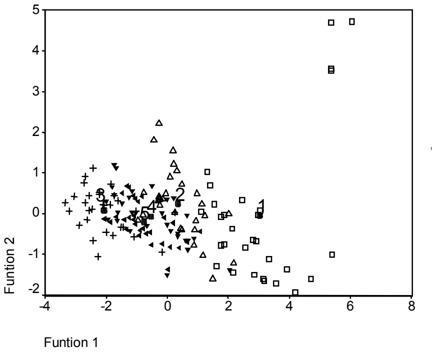
Results and discussion

Ripening changes determination

First, we have done a study about the firmness of the kiwifruits in these five days, we have observed that there are not significant differences between the five days. It could be due to kiwi maturation curve. This curve has three different stages with variable duration. Zoffoli[6] confirms that if kiwifruits are harvested with a low ripening degree they have a long first stage (softening stage). So if we observed our results we can say that our kiwis were harvested with lower maturation.

In the first test, we want to probe the capacity of the NIR to observe little changes in the maturity. With the five different ripening degrees (1st day, 2nd day 5th day) and all NIR variables, we have done a discriminant analysis. The result is that we can classify correctly the 60.7 % of the fruits (Figure 1).

In the second test, we only take the first three days data. The result is that we classify correctly the 86,7 % of the fruits (figure 2). It can be because the kiwifruits ripen faster during the first days.



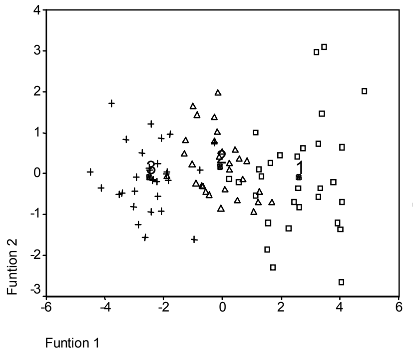


Figure 1. Discriminant analysis using all NIR wavelengths and 5 maturation degrees. (□ 1st day; △2nd day; +3rd day;◄ 4th day;▼ 5th day)

Figure 2. Discriminant analysis using all NIR wavelengths and the first 3 maturation degrees. (□ 1st day; △2nd day; +3rd day)

Soluble solids content determination using multiple linear regression

For this analysis, we have the last day NIR wavelengths and the soluble solids content. We have obtained 11 variables model with R^2 = 0,706 and a standard error of estimate of 0,656 (table 1). This is not a very high error because people can not distinguish differences of the soluble solids content less than 2 degrees.[6]

Table 1. Multiple linear model used to predict the soluble solids content in kiwifruit.

Multiple linear model	R^2
ºBrix = 11,095 + 949,478 L_{2200} – 706,729 L_{2148} – 359,089 L_{1936} + 610,109 L_{1904} – 477,007 L_{1892} – 364,872 L_{1876} + 296,683 L_{1660} + 249,207 L_{1412}+ 87,220 L_{1372} – 316,435 L_{1344} + 45,910 L_{968}	0,706

In addition, we have validated this model with another sample of kiwifruits and we do not observed differences between real and predicted values.

Influence of the temperature in the measures

In this analysis, we have measured the NIR spectra in the same zone of each kiwifruit and at three different temperatures: 0.5ºC, 10ºC and 20ºC. It can observed that if we take the first and the third temperatures (0.5 and 20ºC), the most important NIR bands are near 1440 nm and 2080 nm, but if we work about 10ºC there is a scrolling down and the principal band is around 900 nm (Table 2).

These differences can be explained for the variations of the density in the fruit produced by the change of temperature.

All of NIR bands contain information on more than one type of molecular vibration. In these cases, there is a connection between these bands and the present of carbohydrates.

Table 2. Principal wavelengths of the multiple linear model for each temperature. Coefficient of multiple determination (R^2) and standard error (error).

Temperature	R^2	Error	Wavelengths
0.5 ºC	0,73	0,54	1144, 1148, 1164, 1184, 1264, 1296, 1320, 1388, 1416, 1424, 1448, 1540, 1604, 1816, 1940, 1980, 2052, 2072, 2096, 2156, 2196
10 ºC	0,59	0,67	872, 920, 936, 960, 992, 1040, 1200, 1248, 1316, 1320, 1476, 1528, 1700, 1796, 1828, 1868, 1892, 1908, 1916, 1960, 2140, 2160
20 ºC	0,77	0,51	1416, 1436, 1460, 1492, 1540, 1588, 1616, 1628, 1812, 1820, 1960, 1976, 1980, 1992, 2048, 2072, 2100, 2120

Conclusions

We can deduce from these data that:

- NIR technology can be used as an alternative, non-destructive, method instead of the traditional method (refractometry).
- We can use NIR technology to difference little changes in the maturation of the kiwi.
- Using discriminat analysis and multiple linear regression analysis different statistics models can be defined to obtain good results.
- The relations between NIR spectra and the components of the fruit offer us an important technique to determinate the quality of these commodities.
- There is a scrolling down of the principal bands of the spectra when we take data at 10 ºC.
- NIR technology is influenced by the temperature which we do the essays.

References

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