Tangerines maturity detection by applied spectroscopy

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Abstract The analysis of the optical spectra correlates the analytical maturity data of the obtained juice indicating a trend in the spectral monitoring able to predict the optimal degree of maturity in tangerines. © 2023 The Authors.

1. Introduction

Currently, the cultivation of citrus is one of the most relevant to the countries of the Mediterranean, with a surface area of 513,602 hm^2, of which 57% (295,000 hm^2) are in Spain. In this context, Spain is now the largest producer and exporter of fresh tangerines in Europe, undermined its strong competitiveness in the markets of countries outside the EU [1]. The recollection process is one of the most expensive tasks to be carried out manually in most farms in Spain [2], due to the low level of mechanization of these tasks in our country. The choice of the optimal moment of recollection depends on the index of maturity, the color, and the size [3]. Traditionally the maturity level is estimated in tangerines, and in general citric, based on agronomic conditions, historical crop yield data and visual observations. These visual observations are highly subjective, and depend on experience and knowledge of the techniques, leading to errors which are estimated around 15% and 25% [4]. In the later decades, thanks to the advances in fields such as computer science, robotics, artificial intelligence and digital sensors or cameras, different options have been studied in the so-called Precision Agriculture to estimate the yield of crops. These semi-automatized methods use image capture systems automatically and subsequently apply image segmentation techniques. Many of these techniques use only the spectral response between pixels as a unique feature to detect and count fruits. Most of studies already done conclude that the use of RGB camera (red-green-blue) or multispectral images can be a more than remarkable approximation to the real results, if they are established together. In addition, the use of methodologies for the analysis of images with the using of automatic learning techniques or Machine Learning can recognize the optimum maturity of fruits. These deep learning techniques allow training of a model based on previously obtained data sets and generate with the sorts of this model the classification or the detection of elements in these images automatically. Based on the current information, this study was focused on the development and evaluation of near infrared prediction models to determine quality parameters of maturity degree of tangerines performing analysis of; i) Total volume of juice, ii) Soluble solids, iii) Acidity. The data was validated to find a relation in optical spectrum. These three quality parameters are used to indicate the maturity index, in tangerines based by current Regulation (UE) nº 543/2011. The quality of citrus fruits is defined by the group of fruit owners that complete the existing regulations and satisfy the demands of the consumer. This quality is determined by the proper qualities of the fruit that are essential to be accepted.

2. Experimental

In the study, pieces of citrus fruits of the clementine and satsuma varieties were cropped and collected near the Ebro River (Tortosa). In addition, a second clementine variety of tangerines located in the plateau has been also studied (Pinell de Brai). 5 samples of each variety have been selected in different stages of maturation, from green to mature (Figure 1).

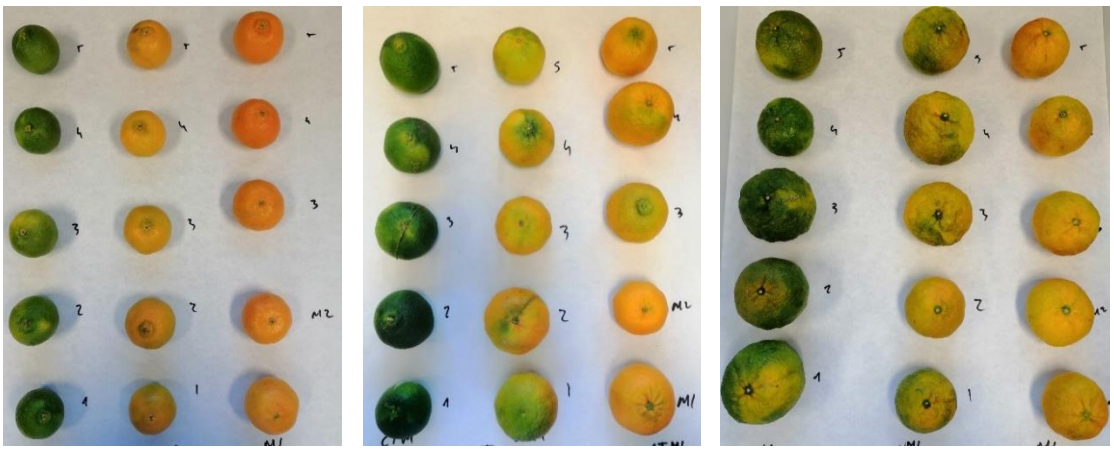


Fig 1. (a) Clementines variety in plateau, (b) Clementines and (c) Satsuma variety close to river.

The analytical and spectral results of each one of the degrees of maturation have been performed as the median of all maturity-variety. In addition, in each of the citrus fruits, 3 spectra have been made in different parts/colors of the pieces. The tangerine samples have been analyzed by using a Neospectra Si-Ware spectrophotometer in the infrared range, between 1300 and 2500 nm.

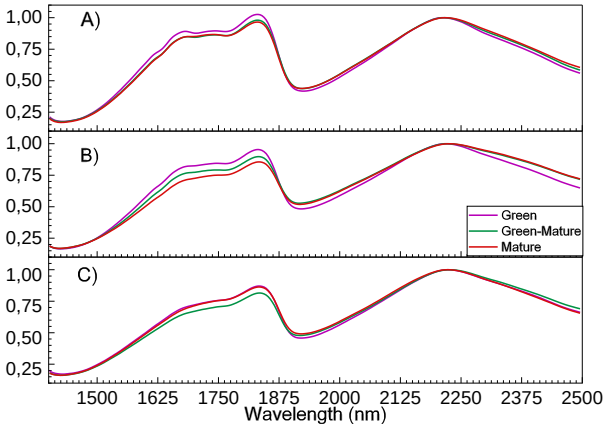


Fig 2. Optical spectra of tangerines: (a) Clementines variety in plateau, (b) Clementines and (c) Satsuma variety close to river.

It has been observed that the trend of the spectral footprint is similar for each of the tangerine class, with characteristic wide peaks between 1800-1850 nm as well as between 2200-2230 nm. As seen in figure 2, no significant fluctuations in wavelength are observed. With respect to the intensity, there is a relationship between the peaks, in these two ranges indicate a correlation between the degree of ripeness of the tangerines. The vertical scale has been normalized and the peak at 2220 nm has been chosen as reference because it was the one with the most intensity compared to most of the points in the cone spectra. However, it does present differences between the range of 1600-1775 nm. A softer zone is observed in the satsuma variety for the different degrees of maturity with a pronounced peak in the clementine variety at 1675 nm. In addition, it also differs between the clementine variety of the different geographical areas, from drier to more humid with a peak at 1750 nm. Table 1 shows the averaged results of the quality parameters obtained as well as the relationship between reference peaks observed in figure 2. In the case of clementines, as the citrus ripens, the % total volume of juice and brix values increase, so the acidity and the ratio between the peaks at 1835-2200 nm are reduced. A direct relationship is observed between the analytical and spectral data. In the case of the satsuma variety, as the citrus fruit matures, the % volume of juice increases as well as brix and acidity values, and the ratio between the peaks at 1835-2200 nm are slightly reduced. The collection of the satsuma variety was done once it's showed an over-matured; so, in this case, it is observed that the weak variability of the data may be because citrus fruits do not present a significant change in maturity between the analytical parameters and spectral data.

	Clementine Plateau				Clementine river				Satsuma river			
	%	ºBrix	Aci.	R	%	ºBrix	Aci.	R	%	ºBrix	Aci.	R
Green	42,3	12,0	2,51	1,03	53,6	11,0	0,90	0,95	46,9	11,4	1,63	0,87
Green-Mature	46,3	13,7	1,61	0,98	54,3	14,0	0,83	0,90	48,1	11	1,63	0,85
Mature	48,5	14,8	1,23	0,97	57,4	14,3	0,82	0,85	50,1	11,1	1,58	0,85

Table 1. Analytical data from % of juice, soluble solids (°Brix), acidity (%) and relation of 1835 and 2200nm peaks (R= $Peak_{1835}/Peak_{2220}$).

3. Conclusions

The relationship between analytical and spectral measurements has been studied to quantify the degree of maturity of tangerines. It has been observed that there is a spectral relationship between the peaks in the 1800-1850 nm and 2200-2230 nm bands. Indeed, depending on the tangerine variety, variations are also detected between 1600 and 1775 nm. The detection of significant differences allows to scale the system in an automated guided vehicle (AGV) or unmanned aerial vehicle (UAV) with specific multispectral band to detect the optimum state of tangerines. It is interesting to highlight as a complement the obtained values ranged between 800 – 1300 nm to have additional spectral information.

[1] Cardeñosa, V., Medrano, E., Lorenzo, P., Sánchez-Guerrero, M. C., Cuevas, F., Pradas, I., & MorenoRojas, J. M. "Effects of salinity and nitrogen supply on the quality and health-related compounds of strawberry fruits (Fragaria × ananassa cv. Primoris)", Journal of the Science of Food and Agriculture, 95(14), 2924–2930 (2015).
[2] Torregrosa Mira, A., Albert Gil, FE., Aleixos Borrás, MN., Ortiz Sánchez, MC., Blasco Ivars, J., "Analysis of the detachment of citrus fruits by vibration using artificial vision", Biosystems Engineering, 119:1-12(2014).
[3] Lado, J., Rodrigo, M. J., & Zacarías, L., "Maturity indicators and citrus fruit quality", Stewart Postharvest Review, 10(2) (2014).
[4] Apolo-Apolo, O. E., Martínez-Guanter, J., Egea, G., Pérez-Ruiz, M., "UAV and Machine Learning Techniques Applied to Yield Estimation of Orange Trees", Proceedings of the 2018 European Agricultural Engineering Conference Wageningen, The Netherlands (2018).