Ultrasonic evaluation of the hydration degree of the orange peel

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The degrees of firmness, turgidity and humidity of fruits are commonly used as a quality indicators in postharvest processes. There exist also a good correlation between these indexes and the elastic parameters of the fruit. Elastic parameters have been traditionally measured by means of penetration tests, which are destructive [1]. This has resulted in the increased attention recently given to non-destructive ultrasonic techniques applied to the quality evaluation of horticultural commodities [2]. Nevertheless, since most of the fruit and vegetables display a viscoelastic behaviour due to the fruit heterogeneous structure, penetration tests [3] should be considered to be quasi-static, especially when compared with the time scales associated with the ultrasonic tests. Both methods should provide different values for the elastic parameters.

In this work [4], we present a non-destructive ultrasonic test for measuring the elastic parameters of the orange fruit peel and its correlation with dehydration processes. Furthermore, we study the discrepancy in the values of the elastic parameters provided by the quasi-static and ultrasonic tests, and interpret the elastodynamic behaviour of the vegetable tissue under an ultrasound test.

First, we perform an experimental test to evaluate the speed of the ultrasonic waves travelling through the sweet orange peel at 40 kHz. The tests were repeated over two sets of oranges (*Navelina* and *Ortanique*), and the complete dehydration process was monitored for two months. Secondly, in order to interpret the results, a linear elastic solid model with viscous losses was numerically solved using a simulation scheme based on a 3D-Spherical FDTD method (Finite-Difference Time-Domain) [4], which proved that the elastic parameters obtained by penetration and ultrasonic tests differ, and the detected waves by the ultrasonic setup were of surface-Rayleigh type waves.

The present method provides an empirical relation between the hydration state and the elastic parameters of the orange peel. Therefore, the proposed ultrasonic test reported in this work is capable of determining the hydration state of the orange by measuring the propagation speed of the Rayleigh waves on the orange peel, and hence, can be used as a fruit quality index during post-harvest processes. Furthermore, the present techniques can be applied to other fruits. In the specific case of apples, surface waves can be excited on the skin. In this case, the elastic parameters of the flesh influences the elastodynamics of the peel, providing a monitoring method of the quality of the inner structures of the fruit.

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