ABSTRACT

The electrical bioimpedance technique provides the characterization of biological systems applying an electrical current in a certain frequency range. By this means the material structure and composition are extracted analysing the electrical properties. Furthermore, the electrical bioimpedance applied to the biological systems provides information about physiological changes in and out of the cell as well as in the membranes and tissues. An advantage of this technique is that it is simple and non-destructive.

Based on several previous studies in nectarine, apple, cucumber, kiwi, kaki and strawberry, the aim of this study was to develop a procedure for the non-destructive assessment of electrical bioimpedance in three strawberry varieties (*Fragaria* x *ananassa* Duch) ('Sweet charly', 'Festival' and 'Camino real'), in order to relate impedance variables to firmness and maturity level. Strawberry fruit was chosen due to its importance in the region of Guanajuato. Six groups per variety were defined according to three maturity level and two equatorial diameter sizes, based on the Mexican law NMX-FF-9-1982. The classification according to maturity level was carried out subjectively considering colour from the strawberry maturity level table. The classification according to size was carried out objectively measuring equatorial diameter with a Vernier caliber.

In order to accomplish this objective, a prototype capable of estimating strawberry impedance was designed and tested. The measurements were performed connecting the prototype to an impedance analyzer. Using the spectrums generated from the analyzer data, the electrical elements values were calculated based on a predefined circuit model, Rs (Serial Resistor), CPE (Constant Phase Element, Magnitude CPE-T and Phase CPE-P) and Rp (Parallel Resistor).

External colour of the strawberries was measured with a spectrophotometer and the coordinates L*, a* and b* were obtained. The colour coordinates were used to relate them to firmness and maturity level.

Significant differences between the three maturity levels according to the colour coordinates were tested with an ANOVA analysis. Results showed that L* value was significantly different in the three "maturity levels". In all the cases, L* value decreased along the ripening process.

The colour difference parameter (ΔE^*_{ab}) was used to analyze colour differences between the three maturity level groups. Signifficant differences were found between the three maturity level groups according to ΔE^*_{ab}.

In order to classify the pre-established maturity level groups according to L*, a* and b colour parameters, a discriminant analysis was carried out. 'Festival' and 'Camino real' varieties showed a high percentage of well classified fruits, 94% and 93% respectivelly.

Significant differences between the three maturity levels according to the impedance variables were tested with an ANOVA analysis. The results were not as expected, a clear tendency was not observed. However, high percentages of well classified fruit were found with a discriminant analysis test classifiying the maturity level groups according to the impedance variables, 84% and 82% in 'Camino real' variety, size B and C respectivelly, using Rs, CPE-P, CPE-T y Rp.
L* as colour variable and CPE-P as impedance variable would better discriminate between maturity level groups in 'Sweet charly' variety; a* and Rs in 'Festival'; and L* and a*, and CPE-P and Rs in 'Camino real'.

Related to the destructive firmness, smaller strawberries were firmer than medium and large fruit. 'Festival' strawberries had higher firmness than the other varieties, followed by 'Camino real' and 'Sweet charly'. Finally, a multiple regression statistical test was used to explain destructive firmness according to impedance variables (Rs y CPE-P) and colour variables (L*, a* y b*).

In 'Sweet charly' and 'Festival' varieties, the regression models based on the colour coordinates, L*, a* and b*, showed higher regression coefficient (R2) than the models based on the impedance variables, Rs and CPE-P. In the variety 'Camino real', the regression models based on the impedance variables, Rs and CPE-P, showed higher regression coefficient (R2) than the other models.