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Review

Cleaner quality control system using bioimpedance methods: a review for fruits and vegetables

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ABSTRACT

Due to the very rapid development of technology as well as the increased demand of quality food, vegetables and fruits are more under spotlights for enhancing their healthy characteristics. With the involvement of new mathematical methods and updated variety of scientific investigations in food science, the need for better characterization of agricultural products arises. This review covers the bioimpedance method used for electrical characterization of fruits and vegetables, known as the bioimpedance spectroscopy. This electrical advantageous method offers an ecological agricultural production. By evaluating the quality factors of horticultural products, bioimpedance targets a double sustainable plan: an environmental friendly food control and an improved consumer's health care at once. An objective interpretation of the quality factors importance in the horticultural sector is presented along with a wide definition of bioimpedance spectroscopy. Moreover, the paper highlights techniques used for the bioimpedance properties measurements since their initiations. The collective data is tabulated for the destructive, non-destructive bioimpedance where clear objectives and focused conclusions of each measurement method are displayed. This paper summarizes the various findings and conclusions of these experiments seeking better oriented investigation in the future and encouraging further quality food applications in areas where data is still ambiguous. Non-destructive bioimpedance techniques open new perspectives for cleaner quality control system in industrial applications for fruit and vegetables quality determination.

Contents

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Nomenclature

AC	alternating current
C1	plasma membrane capacitance
C2	tonoplast capacitance
C_{ef}	effective capacitance
EIS	electrical impedance spectroscopy
FFT	fast Fourier transform
I(t)	current time function
ISR	impedance square root
j	imaginary unit
LCR	inductance capacitance resistance analyzer
MUT	material under test
R	resistance
r	reflection coefficient
R1	cell wall resistance
R2	cytoplasmic resistance
R3	plasma membrane vacuole resistance
R_{ef}	effective resistance
SSC	soluble solid content
TA	titratable acidity
U(jω)	voltage frequency
U(t)	voltage time function
U_0	maximum voltage
U_{inc}	incident voltage
X1	time factor
X2	shape of the fruit factor
X3	size and weight of the fruit
X4	contact area of the probe electrodes
X5	temperature of the fruit
X6	random variation factors
Z	impedance
Z_0	impedance of the transmission line
Z_{ef}	effective impedance
Z_i	impedance imaginary part
Z_r	impedance real part
β	β dispersion
θ	angular phase
ω	angular frequency

1. Introduction

Nowadays the trend is a healthier diet, so decreasing the intake of meat and dairy, and increasing fish (Sánchez-Muros et al., 2014) and seasonal fruit and vegetable products, are needed (López et al., 2015). Due to the very rapid development of technology as well as the increased demand of quality food, vegetables and fruits are more under spotlights for enhancing their healthy characteristics. Engineering practices should be revised continuously to address methodological innovations (Halbe et al., 2015) to reach quality standards production at technical levels. Quality is a term that is frequently used as a multilayered expression that can be usually neutrally or positively occupied (Butz et al., 2005). The origin of the term "Quality" is the Latin word "Qualitas" pointing to the nature or property attribute of the object. Because quality exists only in the minds of the consumer, it may also be defined as the result of all interactions of this consumer (or observer) with a product and its circumstances, the market and its circumstances, and the social situation of the consumer himself. Site measurement of the weight of fruits on the harvester may enhance their market value and present a significant advance in precision agriculture (Qarallah et al., 2008). Thus, quality literally reflects the "acceptability" when speaking in the minds of the consumers. In the agricultural field, optical impression is an essential criterion for a product to be judged as "fresh", and this implies necessarily that special expectations about its internal components are created (Chilar et al., 1987).

Quality of food can be determined through four main factors, as by Bourne classification (Bourne, 2002). First of all, the appearance that involves the shape (Clement et al., 2013), size, color and brightness (Clement et al., 2012). Second, comes the flavor which includes the smell and the taste. The texture of the product comes third by considering the physical stimulus that born through the part of the body contact with food; this phenomenon is known as the "sense of touch". Last but not least the amount of macronutrients (carbohydrates, lipids and proteins) and micronutrients (minerals, vitamins and fibers) which are combined and referred to as the nutrition factor. Apart from some other characteristics, the freshness of vegetables is determined considerably by the water content and the concentration of valuable constituents whereby these items often change rapidly during postharvest decay (Butz et al., 2005).

Seeking an efficient treatment and straightforward marketing, for the producers of agricultural products, the concept of quality involves the cultivation of specific factors such as resistances and

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