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ELECTRICAL IMPEDANCE SPECTROSCOPY AS A POSSIBLE NONDESTRUCTIVE METHOD IN QUALITY ASSESSMENT

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ABSTRACT

The magnitude and phase angle of impedance were measured with a HP 4284A LCR meter on Gala apples purchased on the local market. Two ECG electrodes (Fiab Spa) were applied on apple with skin and without skin at several places on the apple surface along the equatorial. The good electrical contact between the electrodes and apple was realized with a conducting gel. The impedance spectra were determined in frequency range from 10 Hz till 1 MHz at 1 V measuring voltage. Each measured spectrum after an open and short correction was approached by a circuit model consisting of a serial connection of impedance of apple skin and impedance of intracellular and extracellular apple flesh. The complex non-linear least squares method was applied with Mathlab program. This approaching method can allow getting the impedance of apple flesh under the skin without peeling.

INTRODUCTION

The electrical impedance spectrum - in low frequency range - of biological tissues depends on the state of cellular structure (Grimnes and Martinsen, 2000; Vozáry et al., 2007), therefore the parameters evaluated from measured spectrum can be used for quality assessment of fruits and vegetables (Vozáry et al., 2007, Harker and Maindonald, 1994). Recently there is a great demand on non-destructive investigating methods. In this work an attempt was made to determine the impedance parameters of apple tissue from the impedance spectrum measured on the whole apple with skin. The impedance spectrum measured on whole apple with skin was approached with impedance of model circuit consisting of serial resultant of apple skin impedance and apple flesh impedance. The model parameters, characterizing the apple skin and flesh were evaluated.

MATERIAL AND METHOD

Gala apples were purchased on the local market. Impedance along the equatorial (Fig.1.) was measured at two electrode arrangements on apples with and without skin. At first, the two electrodes were same distance – the diameter of the apple - far from each other: the two electrodes were at 1 and 7 point, at 2 and 8, 3 and 9, 4 and 10, 5 and 11, 6 and 12, respectively. At the second measurement one of the electrodes was at 12 point and the other electrode was placed to each point from 1 to 11.

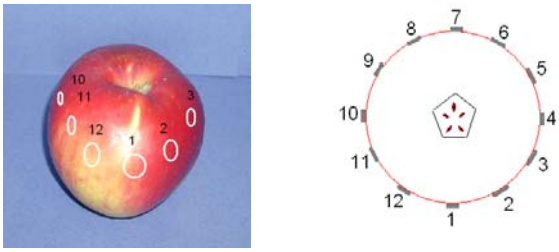

Figure 1

The places of electrodes during impedance measurement on equatorial of apple

The magnitude and the phase angle of impedance were measured with a HP 4284A LCR meter in frequency range from 10 Hz till 1 MHz at 1 V measuring voltage. The apple surface, with skin and without skin, along the equatorial was touched with two ECG electrodes (Fiab Spa). The good electrical contact between the electrodes and apple was realized with a conducting gel. Each measured spectrum after an open and short correction was approached with

impedance of an electrical model circuit consisting of a serial resultant of apple skin and apple flesh impedance.

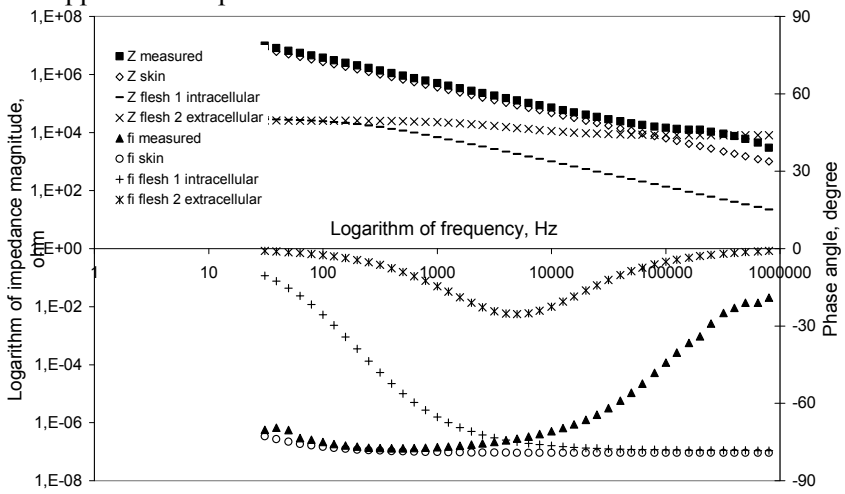

Figure 2
A typical spectrum of magnitude and phase angle of
Impedance measured on apple with skin and the result of approach.
The measured spectrum can be expressed with sum of impedance
of skin, extracellular and intracellular part of apple flesh.

$$Z = R_o + \frac{R - iR^2C\omega}{1 + R^2C^2\omega^2} + \frac{R_1}{1 + i(\tau_1\omega)^{\psi_1}} + \frac{R_2}{1 + i(\tau_2\omega)^{\psi_2}} \qquad (1)$$

The impedance of apple skin was modelled with a parallel RC circuit:

$$\frac{R - iR^2C\omega}{1 + R^2C^2\omega^2}, \qquad (2)$$

where R and C are the resistance and the capacitance of apple skin. The impedance of apple flesh was approached with serial resultant of two distributed elements corresponding to extra cellular and intracellular part of tissue:

$$\frac{R_1}{1 + i(\tau_1\omega)^{\psi_1}} + \frac{R_2}{1 + i(\tau_2\omega)^{\psi_2}}. \qquad (3)$$

The R_1 and R_2 are resistances, the distances between the two intersections of locus curves with real axis, τ_1 and τ_2 are relaxation times, and ψ_1 and ψ_2 exponents characterize the distribution of relaxation times.
R_o is the resistance of apple at high frequencies.

The complex non-linear least squares (CNLS) method was applied in curve fitting with MathLab program. The impedance parameters: the resistances, the capacitance, relaxation times, exponents were determined, too.

RESULTS AND DISCUSSION

The CNLS method can allow getting the impedance of apple flesh separately from the impedance of apple skin using the measured spectrum of whole apple with skin (Fig.2.). The impedance of apple flesh can be described well with resultant of extracellular and intracellular impedance (equation 3). Really, it is known for other living tissues, too, that the impedance of intracellular part differs from the impedance of extracellular part (Grimnes and Martinsen, 2000). For example, the impedance of nectarine fruit can be represented by such model circuit, which contains the extracellular resistance, capacitance and the intracellular resistance, capacitance, too (Harker and Maindonald, 1994).
The impedance locus curve measured on whole apple with skin gives good agreement with the approaching curve.
The value of impedance measured on apple with skin is highest, when electrodes are near to each other. On the other hand the highest impedance on apple without skin can be measured, if the electrodes are far from each other. These results can be explained by the different ratio of current length to current cross-section on the surface of apple, where the skin impedance is determinative, and inside of whole apple, in apple flesh. In the case of peeled apple the current goes through interior of apple.

CONCLUSION

The CNLS approaching method can allow getting the impedance of apple flesh under the skin without peeling.

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EFFECT OF SOY FLOUR, CORN FLOUR AND GLUTEN ADDITION ON QUALITY CHARACTERISTICS OF BREADING

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Bread crumbs are typically derived from bread which have been either dried or toasted and are often used in the food industry to enhance the fried-like texture that consumers typically enjoy. In this study, soybean flour (5,10, 15%), corn flour (5,10,15%) and gluten (3,6,9%) were added to bread formulation.

Table 1. The properties of breadings formed from different particle size

	Moisture (%)		Water Binding Cap (g/g)		Oil Uptake (%)		Compressive Force (g)	
p.s.	**small**	**large**	**small**	**large**	**small**	**large**	**small**	**large**
c	7,43	7,85	3,15	3,18	20,00	34,58	3049,3	4769,5
c5	7,83	7,31	2,87	2,71	31,01	19,67	3085,5	5211
c10	8,22	8,21	2,81	2,85	33,15	18,58	3004	4756
c15	8,04	7,83	2,64	2,64	28,79	18,51	3296,5	4543,5
s5	7,23	7,18	2,83	2,87	28,83	32,64	3243,8	3573
s10	7,24	7,7	2,82	2,69	26,66	32,6	3312	3850
s15	7,60	7,85	2,74	2,56	31,66	33,76	5140	6264,5
g3	7,14	7,16	3,17	3,08	16,23	26,09	1872,4	2979
g6	6,69	6,89	3,25	3,10	16,20	28,71	1655,1	2027,7
g9	7,29	7,42	3,45	3,13	16,15	27,51	1984,5	2198,4
LSD	**0,76**	**0,76**	**0,17**	**0,2**	**9,29**	**9,29**	**373,2**	**373,2**