Effects of Pulsed Electric Field on the Viscoelastic Properties of Potato Tissue

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ABSTRACT
We have investigated whether membrane permeabilization would give rise to transient or permanent changes in the potato tissue mechanics. The changes on the viscoelastic properties of potato tissue exposed to PEF during small-amplitude oscillatory dynamic rheological measurements were monitored. The elastic (G') and viscous moduli (G'') were measured every 30 s after the delivery of the pulse and the loss tangent (tan-δ) change calculated. Our results, supported by similar measurements on osmotically hydrated control samples, clearly show that PEF causes a rapid change in the viscoelastic properties of the tissue that could be attributed to a partial loss in turgor pressure. This would be an expected consequence of electroporation. The recovery of tan-δ to values similar to those before pulsation, strongly suggests recovery of cell membrane properties and turgor.

1 Materials and Methods
1.1 Samples
Potato tubers (Solanum tuberosum L. cv. Bintje) grown in the south of Sweden, were manually washed and peeled. A rectangular cross-section sample, 15 mm long and 6.0 mm wide, was obtained from the phloem parenchyma tissue using a pair of parallel sharp blades.

1.2 PEF treatment
- Samples were treated at nominal field strength range of 30 to 500 V/cm, with single rectangular pulses of 1 ms and 10 µs, delivered axially to the tissue;
- Osmotically pre-treated samples were subjected to a single 1 ms pulse in the range of 30 to 500 V/cm. Additionally, a sequence of 9 rectangular pulses of 500 V/cm of 1 ms each was also tested;
- The pulsation for each PEF treatment was given 150 to 200 s after the start of the small-amplitude oscillatory dynamic rheological measurements;
- Five measurements were done for each condition.

1.3 Small-amplitude oscillatory dynamic rheological measurements
The potato sample was placed on the lower plate of the rheometer. The upper plate was brought into contact with the sample until a normal force of 1 N was reached. Measurements of the tan-δ were recorded in the oscillatory mode as a function of time at intervals of 30 s. The oscillation stress amplitude was 0.1 % of the maximum stress.

2 Results

2.1 Tan-δ measurement during PEF treatment
- Tan-δ change was calculated by subtracting the tan-δ values measured at time intervals of 30 s after pulsation by the initial value of tan-δ, immediately measured before pulsation (Figure 2a). The values corresponding to the initial stabilization of the oscillatory measurements were then subtracted (Figure 2b and Figure 3).

2.2 Tan-δ recovery
- Total permeabilization of the tissue reached similar values when widths of 1 ms, 100 µs and 10 µs were applied during pulsation, particularly for 500 V/cm.
- At pulse widths of 10 µs, a drastic decrease of the electrical resistance of the tissue was not accompanied by a measurable viscoelastic response.

3 Conclusions
I. Small-amplitude oscillatory dynamic rheological measurements for potato tissue show evidently that PEF treatments give rise to dynamic changes of its viscoelastic properties;
II. The initial increase of the tan-δ values could be attributed to a partial loss in turgor pressure;
III. This increase, an expected consequence of electroporation, was strongly dependent on the pulse conditions;
IV. At certain PEF conditions, the recovery of the tan-δ to values similar to those before pulsation was observed, suggesting the recovery of cell membrane properties and turgor;
V. This study has also raised in interesting questions regarding different events taking place in the cells upon reversible electroporation. The complex cell stress physiology involving both cell membrane functional properties and cell wall structure would influence the physical properties of the tissue in a pattern that needs to be further explored at the micro or nanoscale level.

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References