CHARACTERIZATION OF THE CELLULAR STRUCTURE OF MESOPHYLL TISSUES OF PLANT LEAVES USING AIR-COUPLED ULTRASONIC SPECTROSCOPY

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A non-contact and through transmission ultrasonic technique is proposed for the characterization of the cellular structure of the Mesophyll tissues in plant leaves. The mechanical properties of the tissues are extracted from measurement of the thickness resonance spectra by solving the inverse problem. Furthermore, the second order of thickness resonance is also measured. Compared with model predictions, the results show a distortion of the frequency pattern of the spectra of the first two orders of the thickness resonances. The observed distortion degree is variable and experimental evidences suggest, so far, that it may depends on the tissues layered microstructure, cell shape, cell wall rigidity and turgor pressure, among others.

EXPERIMENTAL RESULTS

<table>
<thead>
<tr>
<th>v (m/s)</th>
<th>p (kg/m³)</th>
<th>th (μm)</th>
<th>Cₚp, (Mpa)</th>
<th>α (Ns/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Populus x. euroam.</td>
<td>305</td>
<td>722</td>
<td>223</td>
<td>67</td>
</tr>
<tr>
<td>Ligustrum *</td>
<td>353</td>
<td>1038</td>
<td>692</td>
<td>130</td>
</tr>
<tr>
<td>Vitis *</td>
<td>317</td>
<td>927</td>
<td>238</td>
<td>93</td>
</tr>
<tr>
<td>Epipremnum a.</td>
<td>205</td>
<td>821</td>
<td>414</td>
<td>35</td>
</tr>
<tr>
<td>Nerium a.</td>
<td>284</td>
<td>892</td>
<td>565</td>
<td>72</td>
</tr>
</tbody>
</table>

I. Analysis

• Frequency distortion < 1
• Classical wave dispersion

• Two alternative solutions:

II. Analysis f₁ and f₂

• Frequency distortion > 1

Acoustically Layered Mesophyll:

• In many cases agree with Mesophyll structure

Anomalous Low Frequency Wave Dispersion:

• Both velocity and attenuation increase with frequency
• Similar behaviour observed in soft foams in contrast to rigid foams

CLASSIFICATION OF THE TISSUES ATTENDING TO THEIR ACOUSTIC RESPONSE

Degree of Mesophyll heterogeneity +

Degree of armonic distortion (>1) +

HOMOGENEOUS (MONOCOT) TISSUE, NON-DISPERSIVE

Examples:

Dracaena marginata

QUASI- HOMOGENEOUS (DICOT) TISSUE NON-DISPERSIVE

Examples:

Populus x. euroam.
Ligustrum lucidum
Vitis vinifera
Eucalyptus

HOMOGENEOUS (MONOCOT) TISSUE, DISPERSIVE (ANOMALOUS)

Examples:

Platycerium bifurcatum
Phormium tenax
Aspidistra elatior

QUASI- HOMOGENEOUS (DICOT) TISSUE , DISPERSIVE (ANOMALOUS)

Examples:

Epipremnum aureum
Vitis vinifera
Hedera helix
Prunus laurocerasus
Acer platanoides
Ligustrum lucidum

The acoustic properties of the mesophyll of a leaf depends not only on the species but also on the maturity of the tissue, the environmental conditions where it grows, the turgor pressure...

• Leaves effective parameters like Cₚp, density and ultrasonic velocity, and attenuation are obtained from magnitude and phase spectra measurements of the first thickness resonance by solving the inverse problem.

• In some cases, a distortion of the resonance pattern is observed. This distortion can be conventional or anomalous, two explanations are provided for the second case: heterogeneous Mesophyll structure or anomalous wave dispersion similar to that found in other flexible foams.