BROADBAND DIELECTRIC CHARACTERISATION OF BOVINE MEAT.

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I - INTRODUCTION

Accurate measurements of dielectric properties are essential for fundamental studies and they have been the object of numerous publications but their exploitation remains limited, due to the narrow frequency bands used. More recently, the study of a measurement system able to control in real time an automatic machine for bovine carcass deboning has given a new interest to this type of measurement. The present work for the dielectric characterisation, uses a broadband upto at least 20GHz, on different bovine tissues. Results have been obtained at the Meat Research Station of INRA, and at Department of Microwaves and Semiconductors of the IEMN (North Institute of Electronics and Microelectronics).

II - EXPERIMENTAL TECHNIQUES

2.1. MEASUREMENT TECHNIQUE

The main measuring device used at INRA is a network analyser HP 8753C. It is associated to a coaxial probe in APC7mm standard (kit HP 85070A) covering the range from 200MHz to 6GHz. The probe is mounted on a system designed to control the pressure applied on the tissue sample under test. At IEMN, the measurement device is an network analyser HP 8510B covering the range 45MHz to 26GHz. It is connected to different types of measuring cells: an open coaxial cell from General Radio for 100MHz to 2GHz, with dimensions: $\Phi_{int} = 6.2mm$, $\Phi_{ext} = 14.28mm$, length of the sample, h=6mm.; a rectangular wave guide cell in the frequency range 8.2 to 12.4GHz with a section dimension of 22.86mm x 10.16mm and length of the sample, h=10mm. Each device, with associated cells, is driven by an online computer connected to the different peripherals. The temperature is regulated at 10°C with a water regulation system.

2.2.STUDIED SAMPLES

Representative samples were taken from one bovine carcass:
muscles *Tensor Fascia Latae* (shortened TFL), *Rectus Abdominus* (RA) and *Pectoralis Profundus* (PP), and different types of tissues as connective tissue of RA (TCRA), tendon (TD), and kidneys fat (GR). The measurements were carried out at INRA as well at IEMN on tissues from the same carcass at 48 hours and 8 days *post mortem*. The samples were cut using a razor blade (especially for the rectangular guides probes and cells) or with a punch that is unfortunately more destructive (in the case of measurement using coaxial cells). Good contacts was maintained between sample under test and surfaces of the cells used or surface of probes so to avoid loses caused by a gap of air or liquid.

Samples are prepared in such a way that two series of measures could be taken: for $\varepsilon^*_{//}$ (fibres oriented in the direction of the electrical field, as far as possible) and the other for $\varepsilon^*_{\perp}$ (fibres oriented in the direction perpendicular to the field).

III - RESULTS AND DISCUSSION

Utilisation of these different probes and cell geometries, prepared from the same tissues, underscore the difficulty to link the results obtained. Before to envisage the dielectric characterisation of different biological tissues, it is essential to put in obviousness influences of some parameters.

3.1. RESULTS ANALYSIS

Repeatability of results. As example, we present results obtained with TFL on figures 1a and 1b at t=8 days and T=10° C.

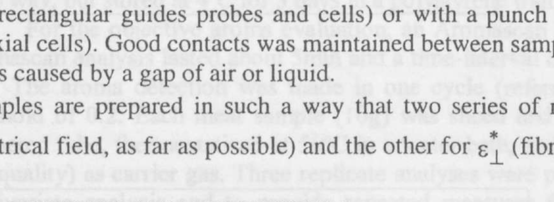

Figure 1a: Repeatability of measurements for ε'

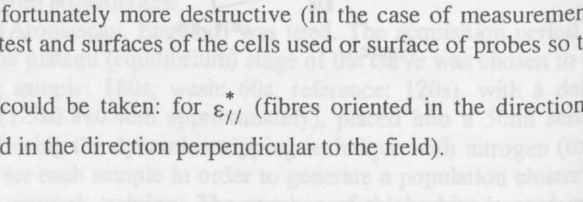

Figure 1b: Repeatability of measurements for ε"

Measurements show shifts or tilts in reproducibility in the order of 10% in the case off ε', and 15% for ε".

Nevertheless, gaps are generally lesser for samples with low water contents (t=8 days) and for cells where the adjustment of the sample is less destructive (probe as compared to coaxial cell). To minimise this dispersion, results should be averaged from at least three samples (cf. figure 1a) which was done for the results in figure 2.

Effect of temperature. The effect of sample temperature on dispersion has been studied on muscles between 6 and 15°C. Measurement errors became perceptible above 6GHz, only on ε", indicating the beginning of the water relaxation domain, situated near 24GHz at ambient temperature. This shows that the measurements are not sensitive to temperature which was set at nearly 10°C.

Anisotropy studies. In order to study anisotropy effects, we have compared results obtained on different types of muscles and at different post-mortem times. According to field directions in relation to fibre orientations, differences of permittivity were small but larger than errors of measurement. They are more important with the rectangular cell waves guide (in which samples are perfectly oriented) than with the probe (because of radiation effects) or than with the coaxial cell (in which radial fields does not allow the measurement of $\varepsilon^*_{//}$). For these reasons, we present subsequently only measurements of $\varepsilon^*_{\perp}$.

Thermal treatments effects. A study on thermal cycle influence (freezing and thawing) on muscles has shown important gaps in the all frequency bands confirming previous studies. For this reason, further measurements were made on samples that have undergone no thermal treatment.

3.2 STUDY OF DIFFERENT TISSUES

Permittivities of the different tissues are shown in figures 2a and 2b.

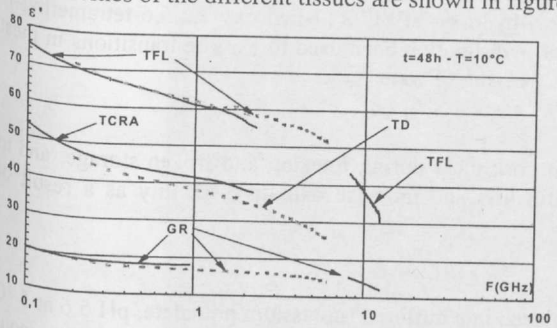

Figure 2a: dielectric constant ε' of studied tissues

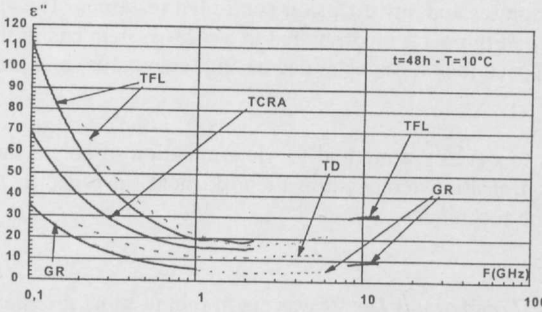

Figure 2b: dielectric loss factor ε" of studied tissues

Results show good covering of ε' (differences less than 5%) between measurements done at IEMN (continuous lines) and at INRA (discontinuous lines) on muscle (TFL) and on kidney fat (GR). It is clearly poorer on ε" at lower frequencies (<1GHz), when the sample (in TFL) shows large loss effects probably owing to the water. For connective tissues of *rectus abdominus* (TCRA) and tendon (TD), only single curves are presented because the probe is not suitable for thin tissues (as TCRA) and tendon samples (TD) suitable for the coaxial cell are difficult to cut. Permittivities were very different between tissues, showing the potential of the dielectric method. It emerges from this study that tissues of bovine carcass can be differentiated by the help of the dielectric permittivity measurements and more particularly of its real part ε'. In order not to be affected by typical Maxwell-Wagner mechanisms and by water relaxation domain, this measurement has to be made between 500MHz and few GHz. The existence of this "window" of frequency has been shown on others materials with various water contents. A recognition sensor has, consequently, to function in this band width. Several systems with coaxial lines and striped lines have been realised in this aim. But this imposes difficulties for the interpretation of the measurements, owing to the presence of air or liquid gaps and in applying pressure to the sensor. Studies are under way to eliminate these disadvantages.

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