POLARIMETRIC OHMIC PROBES FOR THE ASSESSMENT OF MEAT AGEING

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Introduction

A frequent criticism advanced by consumers is the lack of consistent meat tenderness and thereby it is one of the major problems to be resolved by the meat industry. It is well known that meat tenderness depends on the properties of the muscle fibres and the amount and type of connective tissue. Intramuscular connective tissue is rather immutable and contributes to a "background toughness" of the meat (Purslow, 2005). Meat tenderness is improved during refrigerated storage by factors of physico-chemical nature and of enzymatic nature but the ageing rate is tremendously variable (Zamora *et al.*, 1996). A possible way to optimise the duration of refrigerated storage is to assess the ageing state early in the *post-rigor* phase and to classify the meat according to rate of ageing (Lepetit and Hamel, 1998). The assessment of ageing state can be done by different biological or mechanical laboratory means. Biological methods are time consuming and mechanical ones are destructive. The development of rapid and non destructive methods which can give the same information on-site is needed. The structural modifications of the meat which occur during ageing affect not only the mechanical properties but also the electric and dielectric properties of the product (Swatland, 1980, Damez *et al.*, 2005) and particularly the anisotropy of these properties (Lepetit et al 2002). In this study, we attempted to demonstrate the feasibility of a sensor of ageing, useful in the meat industry, based on a measure of the electric anisotropy of the meat.

Materials and Methods

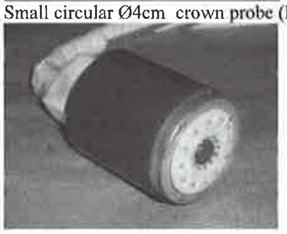
The sensor (under patent) that we designed is suitable to measure the anisotropy of the impedance properties with a single application, by quickly carrying out a multitude of measures in various directions within the muscle. Two probes with circular shape and different diameters were used in this study (Figure 1). The first one (P1) is 8 cm in diameter and has 10 pairs of stainless electrodes (1.65mm in diameter, 15mm in length). The second one (P2) is 4 cm in diameter with an external silver-plated crown and a central silver-plated contact to inject the current and 12 pairs of golden-plated needles, to measure the voltage, which are 2mm in length and 0.6mm in diameter. The impedance measurements were made with a HP 4194A Impedance/Gain-Phase analyzer at a frequency range of 1 KHz to 1.5 MHz and communication between the pairs of electrodes were carried out with an Analog Devices. Curves fitting with Matlab 7.0 were carried out using the equation:

$Z_\theta = Z_\parallel \cos^2\theta + Z_\perp \sin^2\theta$ where Z_θ is the impedance at θ angle with regard to the muscle fibres axis, $Z_\parallel$ is the minimum impedance (measured parallel to the direction of muscle fibres), $Z_\perp$ is the maximum impedance (measured perpendicularly to the direction of muscle fibres)(Figure 2). Statistical analyses to extract pertinent parameters were performed using SAS. The trials to evaluate ageing have been done on a population of 104 bovine muscles (28 *Rectus Abdominus* (RA) muscles, 48 *Semimembranosus* (SM) muscles, 28 *Semitendinosus* (ST) muscles). The electrical measurements have been put correlated with the mechanical stress at 20% of the compression assessed on raw meat samples using an Instron 5543 according to Lepetit and Buffiere, 1995.

Figure 1:
The polarimetric ohmic probes.

Circular probe Ø8cm 20electrodes (P1)

Small circular Ø4cm crown probe (P2)



Results and Discussion

The validation test was carried out both in all (312 samples) and on the means (104 data) of the muscles. Three classes of ageing were arranged (aged < 10 N/cm², 10 N/cm² < mid-aged < 30 N/cm², not aged > 30 N/cm²). The database of 104 muscles comprises 51 aged muscles, 38 mid-aged muscles, 15 not aged muscles according to a classification carried out by the stress compression with 20% compression. In the database of 312 samples, 153 are aged, 114 are mid-aged and 45 are not aged. Good correlations were obtained between the results from the probes and the mechanical compression measurements, particularly those obtained with the P1 probe (Figure 3). The results of the discrimination using each polarimetric ohmic probe are presented (Table 1) from a set of 128 variables and a reduced whole brought back to 36 averaged variables showing that both sensors are performing in some cases a classification close to 90%.

Conclusions

The performances of the two probes presented here are good enough to carry out non-invasive on-line classification of bovine muscles, according to their ageing state, permitting the optimisation of refrigerated storage duration. The integration in the sensors of electronics on the one hand to measure impedance and to perform communication between the electrodes, and on the other hand to carry out calculations in order to obtain a display of measurement, ought to allow in the near future the availability of equipment able to assess the state of ageing for an optimization of refrigerated storage duration and consistency of the meat tenderness.

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Figure 2: Radial plot of impedances measured with the 8 cm in diameter probe (P1), at 10 KHz of a bovine *Rectus Abdominus* (RA) muscle aged for 2, 7, 15 and 23 days.

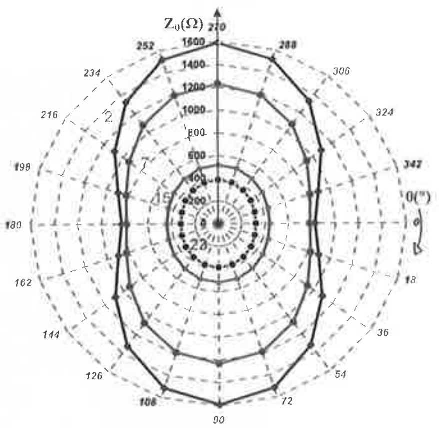

Figure 3: Correlations between the electrical and the mechanical measurements.

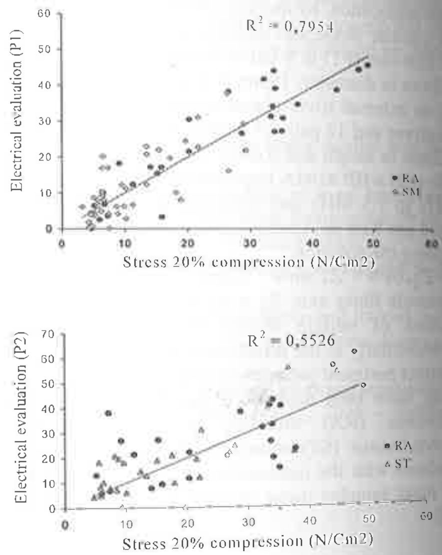

Table 1: Results of the discrimination analysis between 3 states of ageing using the two polarimetric ohmic probes.

	Nb observations	Nb parameters	Discrimination Aged	Mid-aged	Not aged
Circular probe 20 electrodes (P1)	312	36	115 (**75%**)	73 (**64%**)	34 (**76%**)
	312	128	135 (**88%**)	92 (**81%**)	40 (**89%**)
	104	36	45 (**88%**)	26 (**68%**)	13 (**87%**)
Small circular crown probe (P2)	312	36	104 (**68%**)	68 (**60%**)	31 (**69%**)
	312	128	124 (**81%**)	84 (**74%**)	37 (**82%**)
	104	36	37 (**73%**)	30 (**79%**)	13 (**87%**)

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