Electrical anisotropy of beef meat during ageing.

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BACKGROUND

The electrical properties of muscle and meat have been investigated for a long time to determine their potential as quality indicators of meat. Several electrical devices have been developed to predict pH allowing detection of defaults in pork, such as pale soft exudative (PSE) or dark firm dry (DFD) meat. Although some systems are used in the slaughter line, their validity has been criticised as the correlations obtained with quality vary greatly (Forrest *et al.* 2000; Garrido *et al.* 1994). Electrical measurements have also been used to evaluate the level of fat in meat (Slanger & Marchello, 1994).

After a rapid *pre-rigor* drop, electrical impedance of meat decreases more slowly during ageing as shown by Callow (1939), Salé (1976), Pliquett *et al.* (1995) and Byrne *et al.* (2000). This *post-rigor* decrease is strongly linked to the decrease of muscle fibre strength (Lepetit *et al.* 2001). Meat is electrically anisotropic, which means that its electrical properties change depending on the direction of the electrical field in the sample. This has been explained by myofibers being oriented and long, filled with electrolytes and surrounded by a membrane which behaves like a dielectric (Geddes & Baker, 1967). The plasma membrane has usually been considered as the origin of meat electrical anisotropy because during *rigor onset*, the difference in impedance values across and along fibres diminish (Callow, 1939), however the membrane of the sarcoplasmic reticulum may also act as an isolator (Swatland 1987). Soon after rigor, membranes degenerate from their normal laminar structure to scattered, round vesicles, but the kinetics of membranes degradation are not known. Salé (1972) has shown that if non-aged, *post-rigor* meat is frozen and thawed its electrical anisotropy drops from about 2 to 1 and attributed this to a disruption of membranes by the freezing process.

OBJECTIVE

The aim of this work is to study the electrical anisotropy of beef meat during storage and analyse its relationship with ageing.

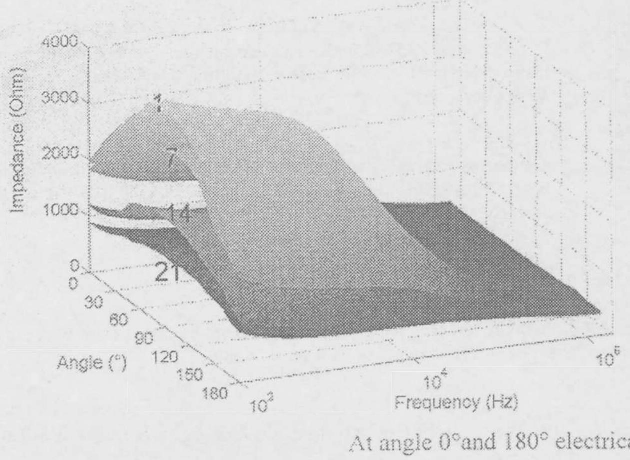
METHODS

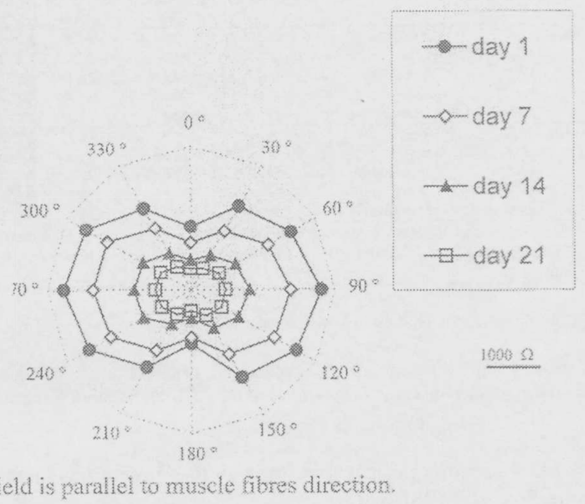
Electrical measurements: Measurements were obtained with an HP 4194A Impedance/Gain-Phase Analyser monitored by a 586 PC and operating in the frequency range from 50 Hz to 15 Mhz. Electrical impedance was measured with a probe made of two parallel steel needles (ϕ=0.6 mm; L= 5 mm) 10 mm apart. The angle between the direction of electrical field and the muscle fibre direction was varied in order to collect series of data for the total 360° distribution of electrical impedance. Values at 0° and 180° correspond to measures for which the electrical field was parallel to muscle fibres direction. The step of increase was 10° or 30°. Meat samples were obtained from *Semimembranosus* muscle of a cull cow at 1day *post-mortem* and stored at 4°C. Samples were maintained at 10°C during acquisition. Measurements were taken at 1, 7, 14 and 21 days *post-mortem*.

Mechanical measurements: The mechanical resistance of raw muscle fibres was measured by compression according to the method of Lepetit and Buffiere (1995).

RESULTS

The variation of impedance with the direction of electrical field and frequency current is plotted in figure 1. A strong anisotropy was observed at low frequencies but it disappeared at high frequencies. The anisotropy at low frequencies decreased progressively with ageing.





At angle 0°and 180° electrical field is parallel to muscle fibres direction.

Figure 1 : Variation of electrical impedance with frequency and the direction of electrical field in meat at 1, 7, 14 and 21 days *post-mortem*.

Figure 2 : Polar representation of impedance at 1 kHz frequency. The bar represent 1000 Ω in any directions

The polar representation of impedance at a frequency of 1kHz shows clearly the change in anisotropy of meat during ageing (figure 2).

During ageing the difference between impedance measured perpendicular and parallel to muscle fibres decreases almost linearly with muscle fibre mechanical resistance as seen in figure 3.

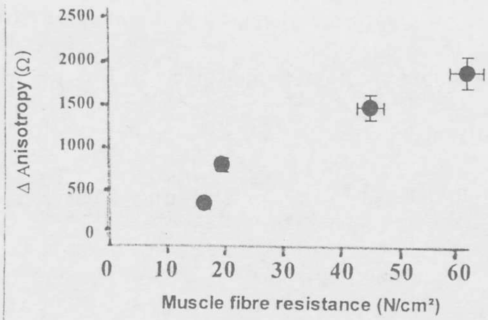


Figure 3 : Variation of the anisotropy with the mechanical resistance of muscle fibres during ageing.
Δ anisotropy = (impedance ⊥) – (impedance //)
Each point is a mean from 5 measurements.

DISCUSSION

This study showed that meat anisotropy is of dielectric nature as this anisotropy almost disappears at high frequencies. Membrans have been proposed as the structural origin of meat electrical anisotropy because they behave like capacitors. Meat anisotropy decreases during *rigor onset* due to progresive disruption of membranes (Calow 1939) but this work shows that there is also a progressive decrease in meat electrical anisotropy during ageing. This can be explained by the progressive desappearance of the membran vesicules or by the modification of another dielectric structure. These phenomena are concommitant with the physico-chemical and biochemical phenomena which are responsible for a progressive decrease of the mechanical resistance of muscle fibres. There is a linear relationship between the decrease in electrical anisotropy of meat and the decrease in mechanical resistance of muscles fibres during the *post-rigor* period. The average meat electrical anisotropy, expressed as a difference, tends to 0 with ageing, that is when the muscle fibre resistance tend to 4 N/cm^2.

CONCLUSIONS

Electrical anisotropy appears to be a potential parameter for the evaluation of *post-rigor* meat tenderisation in a non destructive way. Nevertheless the validity of this method has to be checked on various muscles from different animal types.

REFERENCES

Byrne, C.E., Troy, D.J. & Buckley, D.J. (2000). Post-mortem changes in muscle electrical properties of bovine m. longissimus dorsi and their relationship to meat quality attributes and pH fall. Meat Science, 54, 23-34.

Callow, E. H. (1939). Report Food Invest. Board, 1938, HMSO, London, 55.

Forrest, J. C., Morgan. M.T., Borggaard, C., Rasmussen, A.J., Jespersen, B.L. & Andersen, J. R. (2000). Development of technology for the early post mortem prediction of water holding capacity and drip loss in fresh pork. Meat Science, 55:115-122.

Garrido, M.D., Pedauye, J., Banon, S. & Laencina, J. (1994). Objective assessment of pork quality. Meat Science, 37, (3), 411-420.

Geddes, L. A. & Baker, L. E. (1967). The specific resistance of biological material – A compendium of data for the biomedical engineer and physiologist. Medical and Biological Engineering and computing., 5, 271.

Lepetit, J. & Buffiere, C. (1995). Meat ageing measurement: comparison between two mechanical methods. Fleischwirtschaft 75, 1220-1222.

Lepetit, J., Salé, P., Favier, R. & Dalle, R. (2001). Meat Science, (submitted)

Pliquett, F., Pliquett, U., Schönberlein, L. & Freywald, K. (1995) Impedanzmessungen zur Charakterisierun der Fleischbeschaffenheit. Fleischwirtschaft, 75 (4), 496-498.

Salé, P (1972). Appareil de détection des viandes décongelées par mesure de conductance électrique. Bulletin de l'Institut International du Froid. 2, 265-275.

Salé, P. (1976). The electrical impedance of meat. II^{ème} Congrès International d'Impédance Bioélectrique, 347-355.

Slanger, W. D. & Marchello, M. J. (1994) Bioelectrical impedance can predict skeletal muscle and fat-free skeletal muscle of beef cows primal cuts. Journal of Animal Science, 72, 3124-3130.

Swatland, H. J. (1987). Remote monitoring of post-mortem metabolism in pork carcasses. In, Evaluation and control of meat quality in pigs. Tarrant, P. V., Eikelenboom, G. & Monin, G. 143-163. Dordrecht, the Netherlands, Martinus Nijhoff (ed).