MONITORING *RIGOR* ONSET IN RABBIT MUSCLES BY LOW DEFORMATION MEASUREMENTS

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The aim was to follow the evolution , during *pre rigor* period , of the mechanical properties of rabbit Longissimus Dorsi muscles stored at different temperatures (1-30°C). Muscles removed within 5 min after slaughter were placed in a vibration device which had been built in combination with a compressive machine. For mechanical measurements, samples were pre-strained at 10 % of deformation , and subsequently a 2 % amplitude vibration at 100 Hz was applied every 20 min during the 24 h post-mortem while samples were kept in a chamber at constant temperatures and surrounded by air at saturated humidity. Samples were tested in the longitudinal configuration of the test .A drop in phase lag and internal friction occurred simultaneously with the increase in stiffness at *rigor* and there was a great change in the overall mechanical behaviour , which became less linear. The transition phase , in which mechanical parameters changes was used to determine the time of *rigor* (t_r). Although there was an exponential decay of tr when temperature increased, there was a variation in tr between 0.5 and 2.0 the mean value in controlled conditions of temperature.

Introduction:

Dynamic mechanical testing has been used in different fields of food rheology (RAO 1984). Low deformation tests have been performed to analyse raw meat properties (ALARCON-ROJO 1990) and modifications of the mechanical properties of meat during heating (TORNBERG and PERSSON 1988). FITZGERALD (1975) ,using shear test showed that life to death transition in animal tissues happened with an abrupt transition of compliance and loss tangent. It is well known that the technological conditions in which *rigor* onset occurs can have a great influence on tenderization and therefore a recording of *rigor* onset can be useful in understanding variations in ageing. The purpose of this article was to present a system for the measurement of the dynamic mechanical properties of meat under pre-strained conditions and a set of first results. An analysis of averall results will be presented later.

Mechanical arrangement

The mechanical arrangement of the device is shown in figure 1. The system was built in combination with a TESTWELL type1TZM 748 tensile and compressive machine . Meat samples were compressed between a lower probe, whose movement was produced by an electromagnetic vibrator (Brüel & Kjaer type 4809) and an upper probe, whose movement was produced by the compressive machine The lower probe was attached to the vibrator through a thin metal plate which support the pre-load applied on sample. During the test ,meat samples were maintained between two lateral metal walls kept at constant temperature by circulating fluid. To prevent drying , the samples were surrounded by air at nearly saturated humidity : a few ml of water were put in the bottom of the cell before the test ,after which a plexiglas chamber was put on the cell . An upper and a lower diaphragms nearly close the chamber around the upper and lower probes.

(1) Measurements of forces and deformations.

The samples were submitted to low frequency or static strains by the upper probe and to high frequency strains by the lower probe

Low frequency (or static) load was measured by a strain gauge(SEDEME type AC,100 daN full scale) .

Low frequency (or static) deformation was determined from the position of the upper probe using a displacement transducer and the flexion of the thin metal plate which support the lower probe . Unlike in a similar system (HALAWANI 1983), the flexion of metal plate could occur beyond the range of constant stiffness , and so flexion was determined from a numeric table of correspondences between static load and metal plate flexion obtained with the system without sample.

High frequency load was determined by a KISTLER type 9331 quartz transducer .

High frequency deformation was calculated from the signal of an accelerometer (Brüel & Kjaer type 4366). Acceleration could not be considered as sinusoidal, and so displacement was obtained by a double integration of acceleration.

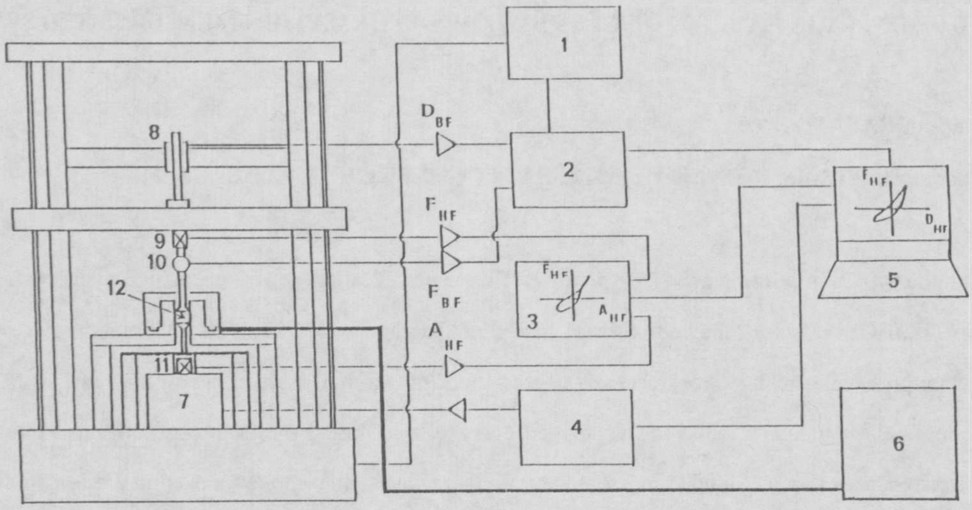

Figure 1 : Shematic representation of the system for low deformation measurements

(1)	mechanical command unit	(9)	quartz force transducer
(2)	data acquisition and control unit	(10)	strain gauge
(3)	oscilloscope with force-acceleration diagramms	(11)	accelerometer
(4)	function generator	(12)	meat sample
(5)	computer with force-deformation diagramms	D_{BF}	low frequency displacement
(6)	thermal regulation	F_{BF}	low frequency force
(7)	vibrator	F_{HF}	high frequency force
(8)	displacement transducer	A_{HF}	high frequency acceleration
		D_{HF}	high frequency deformation

(2) Test conditions

The system allows 3 test procedures controlled by a computer HP VECTRA 386/25 with High Tech. Basic Program.

procedure 1 - Applying HF low deformations at regular time intervals on a sample pre-strained at a definite compression ratio. The data reported here have been obtained with this procedure.

procedure 2 - Applying HF low deformations at different level of compression on a same sample

procedure 3 - applying HF low deformation of increasing amplitude on a sample at a definite level of compression.

In the experiment reported here samples were tested in the longitudinal configuration which is the configuration required for measurement of muscle fibres strength (LEPETIT 1989). Sample height was determined under 0.2N static pre-load detected on sample at 15°C. Then ,samples were compressed at 0.5 mm/min until a 10 % compression ratio and relaxation was followed. As it was observed that the high frequency cycles changed rapidly during the rapid phase of relaxation, vibration was only applied when the rate of relaxation became lower than 1 % par minute .Such a delay before application of vibration was specially important in procedure 3 and was used by HELBER (1980) in a tensile test on muscle fibres. The amplitude of vibration was adjusted to 2% via the computer by monitoring the tension of the generator. Feedback took about one minute . Vibration was applied only every 20 minutes. Force -acceleration cycles were recorded by a NICOLET 4094-A digital oscilloscope.

(3) Mechanical parameters

Maximum stress ,phase lag, internal friction and linearity were determined by computer from stress-strain cycles .According to PERSOZ 1960. internal friction was defined as the ratio of the energy lost by cycle to the energy of vibration. The values reported here were divided by 2π and therefore range between 0 and 1 for a sinusoidal solicitation producing a sinusoidal deformation. The higher the value ,the higher the viscous contribution. For linearity ,a frequency spectrum was obtained by a Fourier transform of the stress signal and linearity was arbitrary defined as the ratio of the amplitude of the fundamental to the sum of amplitudes of all frequencies.

Muscles

Samples of *Longissimus Dorsi* from 62 rabbits (~ 2.5 Kg live weight) were used in this experiment. Muscles were removed within 5 min. after slaughter. Samples (L=1 cm , W=1 cm , l=1 cm) were first placed at 15 °C for positioning then at constant temperature , during about 24 h The range of temperature analysed was 1-30°C.

Results

Phase lag , internal friction and linearity showed a rapid drop when maximum stress increased (Fig. 2). The time of *rigor* , which corresponds to maximum stiffness ,could therefore be determined from the transition of any of the 4 parameters. After that transition ,phase lag, internal friction and linearity stayed at a constant level whereas maximum stress decreased rapidly. Although the duration of *rigor* decreased greatly with temperature (Fig. 3) it showed a wide variation at a given temperature. Pooling the data obtained at different temperatures (Fig. 4), the relative variation of *rigor* duration was calculated. The duration of *rigor* varied within 0.5 and 2 times the mean value in controlled conditions of temperature.

Discussion -conclusion

Muscle under low cyclic deformations behaves like a viscoelastic material but the increase in stiffness at *rigor* is mainly due to an increase in the rigidity of the elastic component compared to viscous one . Indeed , there was a drop both in phase lag and internal friction . SWATLAND (1985) reported a decrease in hysteresis during *rigor* onset but it was not obtained at constant deformation and therefore is more difficult to analyse in term of viscoelasticity in the case of a non linear material like meat. The drop in linearity at *rigor* means that ,not only there is an increase in overall rigidity , but also the dependence between rigidity and strain changes. In figure 2 it can be seen that after the increase in stiffness at *rigor* the stress measured at 2% deformation dropped to rapidly post *rigor* to be able to represent meat ageing. Although different phenomena can produce that drop, there was a small exudation of few % of water which can decrease tension in the

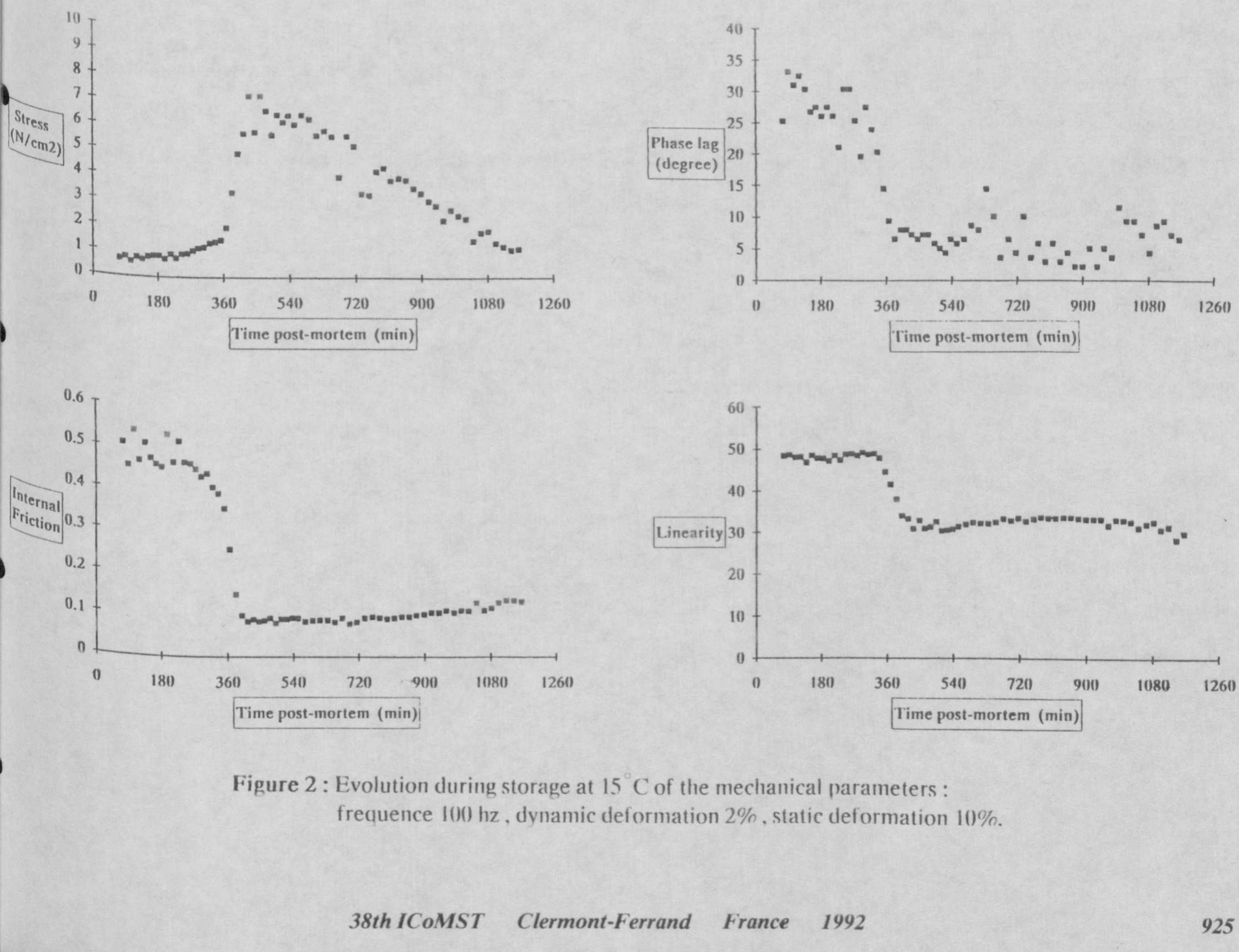

Figure 2 : Evolution during storage at 15 °C of the mechanical parameters : frequence 100 hz , dynamic deformation 2% , static deformation 10%.

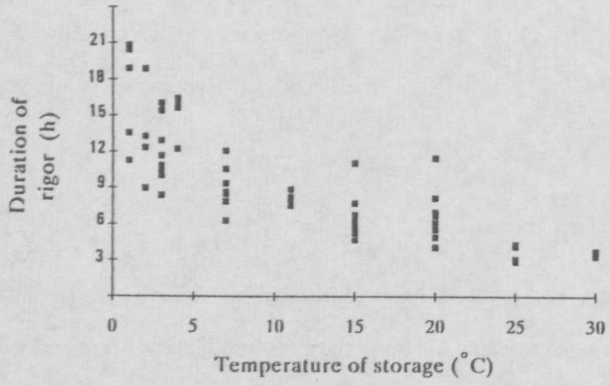

Figure 3: Evolution of the duration of rigor with temperature Muscle Longissimus Dorsi

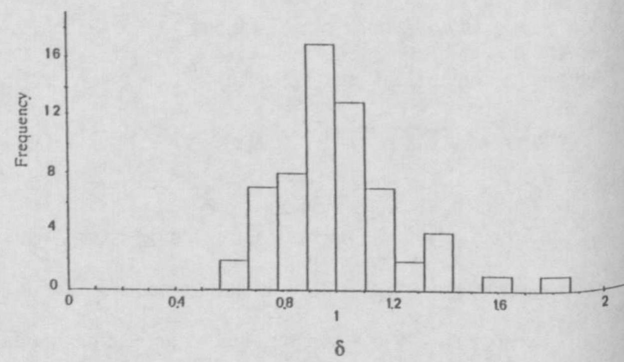

Figure 4: Distribution of the relative duration of rigor δ

$$\delta = \frac{\text{duration of rigor at a temperature } \Theta}{\text{mean duration of rigor at a temperature } \Theta}$$

sample .But also, mechanical fatigue of post *rigor* samples can explain the decrease of stress .The increase of *rigor* duration when temperature decrease until 1°C is in agreement with the fact that fast white muscles do not cold shorten (BENDALL 1973).

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