MEAT TEXTURE ASSESSMENT BY RHEOLOGY, SENSORY ANALYSIS AND ELECTROMYOGRAPHY (EMG)

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BACKGROUND

Texture is a predominant element of the quality and acceptability of meat. It is usually assessed by sensory analysis using trained panels ; but many instrumental methods, mainly rheological ones, have also been developed in order to get an objective assessment of tenderness, the principal component of texture in the case of beef (Culioli, 1995). However, texture is a multidimensional characteristic, perceived all through the mastication process, during which food undergoes continuous changes in structure that are not easy to reproduce with a simple rheological test and which determines the mastication parameters in terms of force, displacement and rate of deformation. Electromyography (EMG) which allows a direct measurement of the activity of the masticatory muscle without disruption of the masticatory process (Brown *et al.,* 1994) may bring a new insight into the understanding of the textural properties. In a previous study, Mathevon *et al.* (1995) used rheology, sensory and electromyography methods to analyse the variations in meat tenderness induced by different cooking temperatures. But meat texture depends on many other technological and biological factors. In the present study the influence of the muscle type (*Semimembranosus* and *Semitendinosus*) and of the state of the myofibrillar structure (cold shortening and different ageing states) on meat tenderness has also been studied using the same approach.

MATERIAL AND METHODS

Meat samples

Semimembranosus (SM) and *Semitendinosus* (ST) M. of a six year old cull cow were excised 1h *post-mortem* and then cut into three equal segments that underwent either cold shortening (CS) or ageing during two (D2) or fourteen (D14) days. Cold shortening was obtained by immersion of samples in plastic bags in melting ice during 48h. The segments assigned to age were immersed in a water bath maintained at 15°C during 24h then at +2°C until required ageing time. Then, each segment was cut into sixteen slices (7x4x2 cm, Lxlxh) with the longest dimension parallel to the myofibres. Twelve modalities were obtained by combining the different factors, muscle (ST and SM), state of myofibres (CS, D2 and D14) and cooking temperature (60°C and 80°C). Vacuum-packed slices were cooked for 30 min by immersion in a water bath maintained at 60°C or 80°C. Samples were then kept frozen at -20°C. Just before characterisation, the samples were thawed by immersion of the plastic bags in a 15°C water rinse for 1h.

Rheological tests

Compression, shear and viscoelasticity measurements were performed, as described by Mathevon *et al.* (1995), at room temperature using an INSTRON Testing Machine (model 4501) equipped with prototype cells (Lepetit and Culioli, 1994) and a controlled-stress rheometer used in the oscillatory mode (CARRI-MED, CSL 100). The following variables were determined : - in compression, stress and energy at 0.2 and 0.8 strains, and compression modulus ; - in shear, maximal stress and energy at maximal stress ; - in oscillatory torsion tests, storage (G') and loss (G'') moduli, and phase angle (d).

Electromyography and sensory measurements

Electromyography recordings and sensory analysis were simultaneously achieved with a panel of eleven assessors (six women and five men, 25-50 years old) trained for sensory assessment of meat texture. Electrical activity of both the left and right masseter and temporal muscles were recorded for each assessor as described by Mathevon *et al.* (1995). EMG allowed calculation of the number of bursts, the chewing time, the mean and maximum voltages, and the sum of the areas of individual bursts (duration x mean voltage of each burst expressed in V.s) on each mastication sequence. To avoid assessors using extraoral clues, samples (cubes of 1.5 cm) were placed into the mouth by the experimenter with a toothpick. During a session, three replicates of the twelve samples were randomly given to each assessor. Each assessor was instructed to perform two slight pressures onto the sample between the molars to assess the elasticity, then to make one or two bites to assess initial tenderness and finally to chew unrestrained. After swallowing, panellists had to evaluate overall tenderness, juiciness and duration in mouth on 10 cm non-structured scales.

Statistical analysis

Statistical analysis of data were carried out with SAS software (version 6.07, 1988). One-way analysis of the variance (muscle, "ageing" or cooking temperature) and Student Newman-Keuls tests were performed and correlation coefficients were calculated on rheological, electromyography and sensory variables.

RESULTS AND DISCUSSION

Results of the analysis of the variance and means separation are shown for the mechanical measurements (table 1), the EMG parameters (table 2) and the sensory assessments (table 3).

Rheological measurements

Mechanical variables were influenced mainly by cooking temperature, slightly by the state of the myofibrillar structure and very little by the muscle type. In compression, the modulus (slope of the stress-strain curve) was the most informative measure to study texture variation : it was significantly influenced by the three factors and was the only compression variable allowing discrimination of SM and ST muscles.

	Fmuscle	SM	ST	Fmyof.	CS	D02	D14	Fcook temp	60°C	80°C
Stress 20% (N/cm²)	5.97NS	31.34a	25.21a	17.01*	37.71a	27.22b	19.88c	30.77**	26.09b	41.27a
Stress 80% (N/cm²)	0.71NS	271.25a	288.12a	82.30***	451.22a	244.87b	142.96c	105.41***	313.68b	437.97a
Energy 20% (J)	1.40NS	0.03a	0.02a	17.10*	0.03a	0.03a	0.01b	12.66*	0.02b	0.03a
Energy 80% (J)	1.83NS	0.85a	0.80a	111.41**	1.13a	0.90b	0.45c	201.37***	0.93b	1.23a
Modulus (MPa)	15.99*	12.74b	14.06a	915.60***	22.70a	12.09b	5.41c	1206.16***	14.17b	23.39a
Max.Stress (N/cm²)	14.48NS	105.17a	117.83a	317.17**	169.25a	94.25b	71.00c	13.72NS	105.33a	117.67a
Energy (J)	12.00NS	0.45a	0.55a	25.00*	0.62a	0.50ab	0.37b	12.00NS	0.45a	0.55a
G' (10^4N/m2)	0.01NS	11.87a	11.68a	9.31*	15.15b	11.07a	9.11a	40.00**	6.39a	17.16b
G" (10^4N/m2)	0.03NS	24.01a	22.39a	9.48*	3.11b	2.19a	1.81a	34.42**	1.32a	3.41b
delta (deg)	0.34NS	11.51a	11.41a	2.25NS	11.72a	11.33a	11.33a	8.69NS	11.72a	11.20a

Table 1 : Mean values, one-way analysis of variance and Student Newman-Keuls test on rheological variables . Different letters in the same row and for the same factor mean that samples were significantly ($p<0.05$) different ; F, Fisher value ; cook temp = cooking temperature ; myof. = myofibre ; ***=$p<0.001$; **=$p<0.01$; *=$p<0.05$; NS=non significant.

The shear variables were significantly influenced only by the myofibrillar status, cold shortened samples being much tougher than even two days ageing. There was, however, a tendency toward higher stress and energy values for ST muscle than for SM and for 80°C-cooked meat than for 60°C-cooked. Viscoelasticity variables allowed to discriminate meat samples cooked at different temperatures, which confirms the results obtained by Mathevon *et al.* (1995), but they could not differentiate the two different ageing states and the two muscles.

Electromyography recordings

	Fmuscle	SM	ST	Fmyof.	CS	D02	D14	Fcook temp	60°C	80°C	Fsubject
Bursts number	1.64NS	48.48a	50.19a	209.97***	68.82a	42.34b	37.41c	58.95***	44.20b	54.48a	60.81***
Chewing time (s)	0.84NS	32.28a	33.06a	278.38***	47.10a	27.35b	23.99c	75.9***	28.93b	36.42a	51.48***
Sum area (V.s)	1.78NS	13.55a	14.11a	403.11***	22.31a	10.55b	8.89c	136.98***	11.38b	16.28a	38.98***
Mean V. (V)	6.11*	0.33b	0.35a	57.79***	0.38a	0.33b	0.31c	14.69***	0.33b	0.35a	89.29***
Max. V. (V)	7.87**	1.82b	1.88a	157.47***	2.14a	1.77b	1.65c	68.92***	1.75b	1.95a	175.43***

Table 2 : Mean values, one-way analysis of variance and Student Newman-Keuls test on electromyography variables. Symbols and abbreviations as in table 1 ; V. = Voltage.

In contrast with the rheological results, the highest F-values in the case of the electromyography variables were obtained for the myofibrillar status (cold shortening and ageing). Cooking temperature also influenced significantly all the EMG variables. Muscle factor had a lower effect on the EMG variables as it influenced significantly only the mean and maximal voltages. These results agree with the fact that chewing pattern is influenced by food hardness (Plesh *et al.* 1985 ; Jack *et al.*, 1993). Tough food induces an increase in chewing time, muscle work preceding swallowing, mean and maximum voltages. The F-values obtained for the factor assessor were very high, especially in the case of the maximal voltage. Beside the fact that variations in EMG signals could be induced by experimental conditions (precise location of the electrodes, skin electrical conductivity) and by physiological parameters (masticatory efficiency, salivary flow (Sakamoto *et al.*, 1989)) inter-assessor variability could be generated by differences in eating and masticatory habits.

Results of sensory analysis

	Fmuscle	SM	ST	Fmyof.	CS	D02	D14	Fcook temp	60°C	80°C	Fsubject
Elasticity	1.64NS	4.9a	4.6a	8.46***	5.3a	4.6b	4.4b	1.00NS	4.7a	4.8a	19.94***
Initial tenderness	22.61***	5.2a	4.3b	119.51***	2.7c	5.6b	6.0a	70.12 ***	5.6a	4.0b	9.11***
Overall tenderness	31.64***	5.6a	4.8b	424.82***	2.4c	6.4b	6.8a	190.22***	6.1a	4.2b	9.22***
Juiciness	13.71***	4.6a	4.1b	20.22***	3.9c	4.8a	4.3b	373.88***	5.5a	3.2b	70.67***
Duration in mouth	13.36***	5.0b	5.5a	397.83***	8.1a	4.0b	3.7c	121.59***	4.5b	6.1a	20.10*

Table 3 : Mean values one way analysis of variance and Student Newman-Keuls test on sensory descriptors. Symbols and abbreviations as in table 1.

As for EMG, the highest F-values were obtained for the myofibrillar status, which could be explained by the large toughness of the cold-shortened samples. However, cooking temperature had a very marked effect on juiciness. All sensory variables, except elasticity, allowed to differentiate the two muscles (SM was more tender and juicy than ST). High F-values for the assessor factor were obtained, but they were lower than those obtained for EMG, probably due to using a non-structured scale.

CONCLUSION

Meat tenderness variations induced by the type of muscle, the state of the myofibres and the cooking temperature were differently assessed by the various methods used in this study. In the conditions used, compression tests were more sensitive than shear and non-destructive torsion tests to detect differences in tenderness induced by the three factors used. Moreover, within each rheological method, the different variables were not influenced to the same extent. So, it is necessary to select the method and the variable the most appropriate to the factor of tenderness variation. By comparing F-values, EMG appeared to be more efficient than rheology to detect differences in tenderness induced by the muscle factor. It was also more sensitive to the variations induced by cold-shortening and ageing than rheology. EMG appeared to be more related to sensory assessment than rheology was. In addition, EMG reflects all the changes occurring in food properties all along mastication and, so, is more adapted than the single-point instrumental measurement to assess textural sensory properties of which evaluations take into account all the mastication sequence.

LITERATURE

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