ULTRASONIC CHARACTERIZATION OF BOVINE MUSCLES

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INTRODUCTION

Ultrasound has been used in non-destructive and non-invasive techniques in order to assess the fatness of live animals and of carcasses. The measurement of the subcutaneous fat thickness was employed with success in pork carcass grading, because of the very characteristic fat deposit of this animal species. By contrast, for bovine and ovine species a large amount of muscular adipose deposits are intra and inter-muscular, so the fat assessment is more difficult to achieve by a simple measurement of the subcutaneous fat thickness. Some other more elaborated techniques must be employed.

The importance of intramuscular fat (marbling) could be vizualized on echographic images of *longissimus* muscle between the 12 th and 13 th rib of the carcass (Brethour, 1990). Indeed, the intramuscular fat gives the picture a very characteristic echogenic aspect. Some other parameters are based on the acoustic measurement such as: speed of propagation, attenuation, backscattering of the ultrasonic waves, spectral analysis of echographic signal. Whittaker *et al.* (1992) used some of these parameters in order to assess the intramuscular fat of bovine muscle by measuring the speed and the attenuation of the ultrasonic waves and by using a frequency analysis of the echographic signals as shown by Park *et al.* (1994). Miles *et al.*(1987) also used the speed of propagation for the evaluation of fat percentage in bovine carcasses. The aim of this study was to use the acoustic parameters (speed of propagation, attenuation and backscattering intensity of the ultrasonic waves) in order to achieve a classification of different muscles from animals of various ages.

MATERIAL AND METHODS

The ultrasonic bench was composed of a temperature controlled water tank in which, vacuum-packed meat samples were placed. The displacement of the ultrasonic transducers (5 MHz) allowed the scanning of the samples. The motors, the emitter-receiver generator connected to transducers, the signal acquisition and treatment were computer controlled.

The meat samples (7 x 5 x 4 cm) were cut from *Semitendinosus* (ST), *Semimembranosus* (SM) and *Biceps femoris* (BF) muscles of Montbéliard veals of 4, 8, 12 or 16 months bred at INRA (Laboratory Growth and Metabolisms of the Herbivores). Every class of age was composed of five animals. Due to meat anisotropy, the samples were analysed with their fibres either orthogonal or parallel to the direction of the propagation of waves. The experiment was achieved at four different temperatures (5, 10, 20 and 30 °C).

A region of interest (ROI), 20 x 20 mm, was scanned by the ultrasonic beam in two orthogonal directions (x and y) with a 1 mm step. 20 planes of 20 lines, corresponding to 400 equidistant points, were obtained.

Speed (m/s), attenuation (dB/(MHz.cm)) and backscattering intensity (V^2, homogeneous to the squared amplitude) were carried out for each of the 400 sounding points of the ROI.

Collagen content of the samples was determined by the Bergman and Loxley (1963) method. The content in dry matter was measured after drying at 105 °C during 24 h. Intramuscular neutral lipid content was determined by the Arneth method (1972).

The mechanical tests were performed on meat samples cooked in a water bath at 55 or 75° C during 30 min. The maximal stress at 20 and 80% deformations were determined according to Fernandez (1996).

Variance and discriminant analysis was achieved using the SAS software (6.11Version). The factors: age, muscle type and castration were tested.

RESULTS AND DISCUSSION

Description of the ultrasonic variables used: "**V**" ultrasonic velocity or speed in the medium (m/s); "**A**" medium attenuation (dB/(MHz.cm)); "**I**," backscattering intensity ($\propto V^2$). "O" and "P" were used respectively for the orthogonal and parallel orientation of muscular fibres according to the direction of wave propagation. The numbers 5, 10, 20 and 30 corresponded to the temperature in °C. Example of variable: VO20 is the orthogonal speed at 20 °C. Mechanical variables: K, compression stress (N/cm^2). 20% and 80% were the compression rates and 55 and 75 °C the cooking temperatures. Example: K8055 is the compression stress at 80% and 55 °C.

Analysis of Variance (TABLE 1)

Dry matter content was significantly ($P<0.001$) influenced by the 3 factors, age, muscle type and castration, which could be related to variations in lipid content although this variable was only significantly influenced by the age of the animals (increase from 0.6% to 1.7% when age increased from 4 to 16 months).The highest collagen content was obtained for BF muscle and the lowest for SM muscle ($P<0.001$). Among the mechanical parameters only those measured in destructive conditions (compression at 80%) were significantly influenced by the age and muscle factors. However, the age effect was dependent of the temperature. At 55 °C, all 4 age classes were significantly different whereas at 75 °C only 3 classes could be obtained (12 and 16 month-old animals could not be differentiated). ST muscle exhibited the lowest mechanical resistance whereas BF and SM resistance were not significantly different. This could be due to the lower thermal stability of the ST collagen as attested by isometric tension tests (results not shown).

The three ultrasonic variables were affected both by the temperature and the configuration of the test. An increase in the measurement temperature from 5 to 30°C induced a 3% increase in the velocity, a 20% decrease in the attenuation and up to a 110% increase in the intensity. When the ultrasonic waves propagated orthogonal to the myofibres, the velocity and the attenuation were, respectively, 1.2% and 75% lower than in the parallel configuration of the test. However, the intensity of the backscattered signal was much higher (x3) in the orthogonal configuration, which could be due to the fact that during propagation the waves were scattered by a greater number of fibre bundles whose dimensions were smaller than the wavelength.

The correlation coefficients between ultrasonic variables and composition (lipid and collagen contents) or mechanical resistance were never higher than 0.5. Moreover, simple as well as multiple linear regression using the ultrasonic variables could not explained more than 40% of the variance in lipids, collagen or mechanical variables in the conditions of our experiment.

Velocity of ultrasound was slightly higher in SM than in ST and BF muscles, and in muscles from castrated animals for both configurations. In twelve month-old animals, parallel velocity also appeared to be significantly higher than in older or younger animals; the lower the temperature, the better the discrimination.

For both configurations and temperatures of 20 or 30°C, the attenuation was significantly higher in muscle from castrated animals than in muscles from entire animals. The intensity of the backscattered signal, especially in the orthogonal configuration, was only significantly affected by the animal age. Young animals exhibited the lowest intensity, which could be due to lower fat contents.

Discriminant Analysis (FIGURE 1)

A combination of all the ultrasonic parameters allowed to correctly classify 78% of samples by muscle type, 78% by castration class and 88% by age class. The best classification scores were obtained for SM muscle and 8 month-old animals. These results were better than the ones obtained by using chemical and mechanical data whose values for castration, muscle and age factors were respectively 64%, 79% and 70%.

CONCLUSION

In spite of the relatively low differences in dry matter, lipid and collagen contents, which did not reflect the existing diversity of meat, it was possible to achieve a satisfactory classification of meat samples according to muscle type, animal age or castration. The ultrasonic methods present therefore an actual potential to classify different types of meat. However, their application requires the determination, in varied configurations, of several acoustic parameters, which, taken individually, are not sufficient to satisfactory characterize meat but once combined could serve as a basis to a classification method.

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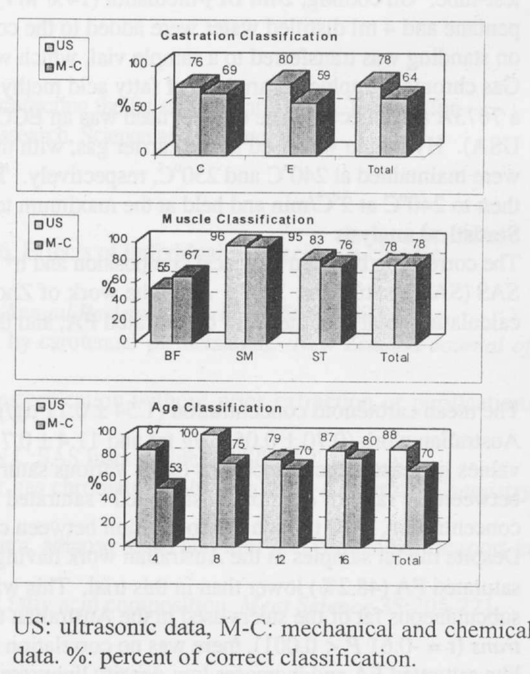
Table 1: Analysis of Variance

Variables	F (Fisher)			AGE (month)				MUSCLES			CASTRATION	
	AGE	MUSCLE	CAST.	4	8	12	16	BF	SM	ST	Yes	No
MS %	10.4***	17.3***	23.9***	24.5 b	25.3 a	25.6 a	25.6 a	25.1 b	25.9 b	24.7 a	25.6 a	24.8 b
LIPID %	55.0***	4.19*	6.15*	0.59 c	0.704 c	1.003 b	1.683 a	0.930	0.880	1.090	1.05 a	0.89 b
COL. µg/g		46.8***						1404 a	938 c	1139 b		
K8055	34.0***	14.7***		78.7 a	92.0 b	114.9 c	132.9 d	112.8 a	110.8 a	88.5 b		
K8075	27.4***	12.5***		105.6 c	126 b	136.6 a	140.7 a	131.4 a	132.8 a	116.1 b		
VP5	10.2***		22.8***	1584 b	1582 b	1596 a	1583 b				1592 a	1583 b
VP10	8***		18.8***	1596 b	1595 b	1606 a	1597 b				1603 a	1595 b
VP20	7.8***	7.6***	11.6**	1617 b	1619 b	1627 a	1618 b	1618 b	1625 a	1618 b	1623 a	1618 b
VP30	5.5**			1630 b	1632 b	1638 a	1629 b					
VO5			10.5**								1565 a	1561 b
VO10		6.3**	7.5**					1575 b	1579 a	1575 b	1578 a	1575 b
VO20		5.8**						1598 b	1603 a	1598 b		
VO30		10.6***						1611 b	1618 a	1613 b		
AP20			7.8**								2.60 a	2.22 b
AP30			13.2***								2.59 a	2.12 b
AO5	12***			0.72 a	0.45 b	0.68 a	0.76 a					
AO20			11.4**								0.67 a	0.53 b
AO30			9.1**								0.66 a	0.54 b
IP5	8.45***			7.6 a	7.3 a	6.3 b	8.2 a					
IP30	4.35**			9.8 bc	11.5 a	9.3 c	11.2 ba					
IO5	27.1***			15.9 c	30.2 a	18.7 bc	21.8 b					
IO10	27.8***			17.1 d	34.7 a	22.1 c	28.2 b					
IO20	24.7***			19.8 c	42.9 a	27.5 b	39.9 a					
IO30	24***			21.4 c	48.6 a	31.3 b	45.8 a					

For ultrasonic variables, only the results for P<0.01 are reported.
On the same line and for the same factor, the results with different letters (a, b, c or d)) are significantly different (P<0.05).V: m/s, A: dB/(MHz.cm)), I: V^2, K: N/cm^2

Figure 1: Discriminant Analysis



US: ultrasonic data, M-C: mechanical and chemical data. %: percent of correct classification.
C: castration, E: Entire (no castration).