HARMONIZATION IN RABBIT MEAT RESEARCH
MUSCLE AND MEAT CRITERIA

OUHAYOUN J.[1], DALLE ZOTTE A.[2]

[1] Institut National de la Recherche Agronomique, Station de Recherches Cunicoles, BP 27, 31326 Castanet-Tolosan Cedex, France
[2] Dipartimento di Scienze Zootecniche, Università degli Studi, Agripolis, 35020 Legnaro, Padova, Italia

INTRODUCTION

The standardisation of methods is essential, as a common base methodology permits comparison between research carried out by different groups and built on by international research programmes. Methods for the assessment of carcass meat quality are extremely variable in terms of approach and usefulness, the latter being different for researchers interested in muscular biology, meat technology or general zootechnical science. Nevertheless, following a recommendation made by OUHAYOUN and RUDOLPH during the 2nd International Colloquy on "The Rabbit as a Model Animal and Breeding Object" (ROSTOCK, 1982), the IVth World Rabbit Congress (1988) suggested a harmonization of meat criteria in rabbit. A first work on carcass measurements and retail cuts was reported in 1990 during a meeting of the Mediterranean Rabbit Group Conference (BLASCO *et al.*, 1992). After consultation among the laboratories working on rabbit meat quality all over the world and discussion during a round table of the Vth World Rabbit Congress, a definitive paper was published (BLASCO *et al.*, 1993). This paper is now considered as representative of the official criteria of the World Rabbit Science Association.

The present paper, which is proposed to the Commission of Harmonization of the WRSA, is devoted to rabbit meat criteria *sensu stricto*.

Each criterion reports a brief definition, its main interest, the principle of its determination and lastly, the general references (the more used in the animal research) and the specific references (the more used in the rabbit research). The paper includes: 1- biological criteria of muscle which are able to determine meat characteristics (i.e. fibre typing), 2- objective meat criteria (i.e. chemical composition, physical or technological properties) which are considered as having some usefulness in the prediction of nutritive value or organoleptic characteristics of meat, 3- subjective meat criteria, components of the organoleptic quality. However, the paper does not deal with the microbiological aspects and ageing of meat. Also, the criteria related, for example, to the ageing conditions or to *post mortem* technological treatments (lipolysis, lipid oxidation, increase of protein extractibility, deamination), are not included. The criteria are listed in alphabetical order.

As muscle and meat are heterogenous, the muscle's name and the location of each piece of meat have to be given. Particularly, if *longissimus dorsi* is studied, it is essential to specify the samples's location (i.e. *longissimus thoracis, longissimus lumborum*); in fact, the fibre composition (VIGNERON *et al.*, 1976) and the related physico-chemical traits (DELMAS & OUHAYOUN, 1990) vary greately according to the anatomical level. Furthermore, it is recommended to remove aponevrosis and tendon and to submit to analysis only the belly of the muscle.

THE CRITERIA

Adipocyte (number and size)

Definition: Type of connective cell containing usual organites, reduced cytoplasm and more or less developed lipidic reserves.
Interest: Extracellular part of total lipid in muscle.

Method: Histochemistry. Cross sections of frozen muscle (10 µm thickness) are fixed in a glutaraldehyde buffered solution (pH 7.4), stained with Oil Red (adipocytes) and Cristal Violet (membranes and muscle fibres). The adipocytes number and area are determined using computerized image analysis system.
General reference: CHORA *et al.*, 1995. Proc. Workshop on Muscle Growth & Meat quality. Rostock (Germany).

Ash (content)

Definition: Mineral residue obtained by incineration of muscle or meat.
Interest: Among the main gross components of muscle and meat.
Methods: Gravimetry. 1- addition of a well known quantity of a magnesium acetate solution to muscle or meat sample, drying at 100°C followed by incineration at 550°C-600°C. The weight of the residue *minus* the magnesium oxide deriving from the magnesium acetate represents the ash content; 2- sample's weight difference after incineration at 550°C, without addition of magnesium acetate solution.
General references: AFNOR, 1968. Dét. des cendres, NF V 04-404 (EQV ISO 936), AFNOR, Paris (France) / ASPA, Commissione Valutazione Alimenti, 1980. Zoot. Nutr. Anim., **6**, 19 / AOAC, 1984. Official methods of Analysis (14th Ed.). Assoc. Offic. Anal. Chem. Washington, DC.
Specific references: PARIGI BINI *et al.*, 1992. Zoot. Nutr. Anim., **18**, 173 / XICCATO *et al.*, 1994. 40th Int. Congress of Meat Sci. Technol., The Hague, The Nederlands.

Buffering capacity

Definition: Ability of the muscle to maintain its pH value (in a given range) owing to the addition of an acid (or a base), or to the production of proton H^+ through the ATP and glycogen breakdown during the *post mortem* period.
Interest: Interpretation of *post mortem* pH drop variations.
Method: Electrometry. The buffer capacity (ß) of the ground muscle is measured by the quantity of strong base (sB) or strong acid (sA) which determines a pH variation of a unit: ß = sA / dpH.
General references: VAN SLYKE, 1922. J. Biol. Chem., **52**, 525 / SAYRE & GAULT, 1989. Meat Sci., **26**, 5.
Specific references: CASTELLINI *et al.*, 1981. J. Comp. Fd Physiol., **143**, 151 / HADDAD *et al.*, 1994. 6èmes J. Rech. Cunic., La Rochelle (France).

Cholesterol (content)

Definition: Steroid of bipolar structure from exogenous (feed) and endogenous (liver, from acetyl CoA) origin.
Interest: Component of cell membranes and indicator of dietetic quality of meat.
Method: Colorimetry. The three steps of the dosage are the following: 1- oxydation of cholesterol (cholesterol oxydase) in d^4cholestenone+H_2O_2. 2- oxydation of methanol (catalase) in formaldehyde, 3- condensation of formaldehyde and acetylacetone in NH_4^+ medium into lutidine dye.
General reference: Boehringer Mannheim Biochemia, 1995. Methods of Enzymatic BioAnalysis and Food Analysis using Test-Combinations. TC cholesterol (139050). Boehringer Mannheim GmbH, Mannheim, Germany.
Specific references: LUKEFAHR *et al.*, 1989. J. Anim. Sci., **67**, 2009 / PARIGI BINI *et al.*, 1992. Zoot. Nutr. Anim., **18**, 173.

Collagen (total content and solubility)

Definition: Fibrous protein made up of tropocollagen molecules synthesised in the fibroblasts, each including three peptidic chains of about 1000 amino-acids. Collagen essentially contains glycine, proline and hydroxyproline. Its different shapes (fibrilles, reticular or connective fibres) surround the muscle fibre (endomysium), the fascicle (perimysium) and the overall muscle (epimysium).
Interest: Total collagen and non-soluble collagen determine nutritive value and toughness of meat, respectively.
Method: Colorimetry. As hydroxyproline (hypro) represents 12.5% of collagenous material (when nitrogen to protein factor of 6.25 is used), the measure of hypro make the quantitative determination of collagen possible. The muscle sample is hydrolysed in H_2SO_4 at 105°C; hypro is oxidized with chloramine-T to pyrrole. The red purple color that develops after addition of 4-dimethylaminobenzaldehyde is measured photometrically at 560 nm. The previous standard heat solubilisation (0.02 M tris-HCl, 0.23 M NaCl, 90°C, 6 h) gives information about the level of collagen reticulation.

General references: ETHERINGTON & SIMS, 1981. J. Sci. Food Agric., **32**, 539 / BONNET & KOPP, 1986. Viandes Prod. Carnés, **7**, 263 / AFNOR, 1987. Détermination de la teneur en L(-) hydroxyproline (méthode de référence), NF V 04-415 (EQV ISO 3496-1978), AFNOR, Paris (France) / AOAC, 1990. Official methods of Analysis (15th Ed., first supplement). Assoc. Offic. Anal. Chem. Arlington, VA, USA.

Colour

Definition: The CIELAB colour space, the most complete method in meat colour estimation, includes three basic parameters: L^* (lightness or brightness), a^* and b^* (redness and yellowness, defined in a system of orthogonal axis) and two derivated parameters: H° [Hue = tg^{-1} (b/a)] and C^* [chroma = $(a^2 + b^2)^{0.5}$].
Interest: Parameters of colour are related to the muscle energy metabolism and to the processing and storage conditions of meat. L^* estimates the reflective power of meat, partially depending on myofibrillar protein structure, itself related to muscular pH; a^* and b^* estimate the meat colour intensity on each orthogonal axis, depending on the concentration of haem pigment and on their oxido-reduction status. H° and C^* estimate the real type of colour and its intensity, respectively.
Method. Reflectometry. L^*, a^* and b^* parameters are measured using Chromameter type CR-100 CR-200 or CR-300 Minolta. The location of the measure, the muscle chilling and cutting conditions before the colour determination are to be standardized.
General reference: CIE, Commission Internationale de l'Eclairage, 1976. Official recommendations on uniform colour spaces, colour differences equations and metric colour terms. Supplement n. 2 to CIE publication n. 15. Colorimetry. Paris (France).
Specific references: BATTAGLINI *et al.*, 1994. Ital. J. Food Sci., **2**, 157 / CABANES *et al.*, 1994. Viandes Prod. Carnés, **15**, 175 / PARIGI BINI *et al.*, 1994. 6èmes J. Rech. Cunic., La Rochelle (France) / XICCATO *et al.*, 1994. 40th Int. Congress of Meat Sci. Technol., The Hague, The Nederlands / PLA *et al.*, 1995. Meat Focus International, **4**, 181 / DALLE ZOTTE *et al.*, 1996. Meat Sci., (in press).

Energy metabolism (balance)

Definition: Biochemical process in living animal producing ATP through glycolytic and oxidative pathways, used by muscle particularly during contraction.
Interest: The balance of these pathways gives an indirect estimation of fibre type composition of muscle (see below).
Methods. Enzymology. Measure of the activity (IU/g) of enzymes, that are representative of each glycolytic and oxidative pathway. The glycolytic pathway may be estimated through the fructose 1,6 diphosphate aldolase (EC 4.1.2.13) activity, the oxidative pathway may be estimated through the NADP-isocitrate dehydrogenase (EC 1.1.1.41) activity.
General reference: ANSAY M., 1974. Ann. Biol. anim. Bioch. Biophys., **14**, 105.
Specific references: BACOU & VIGNERON, 1976. Ann. Biol. anim. Bioch. Bioph., **18**, 675 / DELMAS & OUHAYOUN , 1990. Viandes Prod. Carnés, **11**, 11 / DALLE ZOTTE & OUHAYOUN, 1995. Meat Sci., **39**, 395 / DALLE ZOTTE *et al.*, 1996. Meat Sci., (in press).

Energy value (gross energy)

Definition: Energy value of muscle or meat is the amount of heat evolved by the total combustion of a unit of weight of sample.
Interest: Energy value (Kcal or MJ/g) gives global information on protein, glucid and lipid content of the sample.
Method: Dried or freeze dried ground sample is submitted to complete combustion in oxygen in an adiabatic calorimeter.
General reference: MARTILLOTTI *et al.*, 1987. Metodi di analisi per la valutazione degli alimenti di impiego zootecnico. ISO/339. IPRA. CNR.
Specific references: PARIGI BINI *et al.*, 1992. Zoot. Nutr. Anim., **18**, 173 / HULOT *et al.*, 1994. Meat Sci., **36**, 435.

Fatty acid (composition)

Definition: Organic acid with saturated or non-saturated aliphatic chain of variable length. Their classification is based upon the number and the position of ethylenic linkage. Esterification of fatty acids with several alcohols gives lipids, among which triglycerids and phospholipids (see below).
Interest: Varying according to biological (age, type of muscle) and to zootechnical factors (fat content and composition of feed), fatty acid composition determines the nutritive and the organoleptic value of meat.
Methods: Chemistry and chromatography. Extraction of meat lipids, separation of fatty acids from other constituents by saponification, methylation and analysis by gas chromatography.
General references: FOLCH *et al.*, 1957. J. Biol. Chem, **226**, 497 / DEMARNE *et al.*, 1978. Comp. Biochem. Physiol., **61**, 223.
Specific references: RAIMONDI *et al.*, 1975. Ann. Istituto Sperimentale per la Zootecnia, **8**, 167 / OUHAYOUN *et al.*, 1981. Ann. Zootech., **30**, 325 / OUHAYOUN *et al.*, 1987. Sciences des Aliments, **7**, 521 / PARIGI BINI *et al.*, 1992. Zoot. Nutr. Anim., **18**, 173 / XICCATO *et al.*, 1994. 40th Int. Congress of Meat Sci. Technol., The Hague, The Nederlands.

Flavour

Definition: Sensory property including olfactory (aroma and smell) and gustative (taste) perceptions. The lipid content and composition, as well as interaction with proteins, play an important part; off-flavours and off-odours are often determined by lipolysis of triglycerids (short chain FFA) and peroxidation of polyunsaturated FA (aldehydes and ketones production).
Interest: Among the main subjective criteria of meat quality.
Method. A panel of experts quantifies the flavour according to scale levels (from 6 to 100).
General references: AMSA, 1978. Guidelines for cooking and sensory evaluation of meat. National Livestock and Meat Board. Chicago, Il, 25 p. / CROSS *et al.*, 1978. Food Technol., **32**, 48 / AFNOR, 1991. Contrôle de la qualité des produits alimentaires. Analyse sensorielle. Recueil de normes françaises, 4ème édition. AFNOR-DGCCRF, Paris La Défense (France), 326 p.
Specific references: CABANES *et al.*, 1994. Viandes Prod. Carnés, **15**, 175 / XICCATO *et al.*, 1994. 40th Int. Congress of Meat Sci. Technol., The Hague, The Nederlands / DALLE ZOTTE *et al.*, 1995. Coniglicoltura, **6**, 33.

Haem pigment (content)

Definition: Prosthetic group of the myoglobin, specific muscle protein the function of which is to carry oxygen from blood to myofibre, and of the residual blood hemoglobin.
Interest: Main component of muscle and meat colour, exposed to the oxido-reduction reactions.
Methods: Chemistry and spectrophotometry. Extraction of haem pigment (Fe^{3+}) by acetone, water, HCl. Absorbance measure of the solution at 512 nm.
General reference: HORNSEY, 1956. J. Sci. Food. Agri., **7**, 534.
Specific references: OUHAYOUN *et al.*, 1982. II. Int. Kolloquium "Das Kaninchen als Modelltier und Züchtungsobjekt". Rostock (GDR) / DALLE ZOTTE & OUHAYOUN, 1995. Meat Sci., **39**, 395.

Juiciness

Definition: Sensory property which derives from: 1- water release at the beginning of chewing, determined by meat water holding capacity and pH, 2- salivation stimulated by meat lipids content.
Interest: Among the subjective criteria of meat quality.
Methods: A panel of experts quantifies the juiciness according to levels scale (from 6 to 100).
General references: AMSA, 1978. Guidelines for cooking and sensory evaluation of meat. National Livestock and Meat Board. Chicago, Il, 25 p. / CROSS *et al.*, 1978. Food Technol., **32**, 48 / AFNOR, 1991. Contrôle de la qualité des produits alimentaires. Analyse sensorielle. Recueil de normes françaises, 4ème édition. AFNOR-DGCCRF, Paris La Défense (France), 326 p.
Specific references: CABANES *et al.*, 1994. Viandes Prod. Carnés, **15**, 175 / XICCATO *et al.*, 1994. 40th Int. Congress of Meat Sci. Technol., The Hague, The Nederlands.

Lipids (total and free contents)

Definition: Esters of fatty acids and of various and more or less complex alkohols. Muscle lipids consist on phospholipids of muscular contractile fibre, fibroblasts and adipocytes membranes, glycerides particularly located in adipocytes surrounding fibres and bundles, and free fatty acids.
Interest: Determine the nutritive value and the organoleptic quality of meat.
Methods for total lipids: Extraction and gravimetry. The muscle or meat sample is treated with boiling HCl in order to release linked or masked lipidic fractions. After filtration and drying, the residue is extracted by n-hexane or petrol ether or di-ethyl ether (soxhlet). The extract is dried and weighed.
General references: AFNOR, 1968. Détermination de la teneur en matière grasse totale, NF V 04-402 (EQV ISO 1443), AFNOR, Paris (France) / AOAC, 1984. Official methods of Analysis (14th Ed.). Assoc. Offic. Anal. Chem. Washington, DC..
Specific references: PARIGI BINI *et al.*, 1992. Zoot. Nutr. Anim., **18**, 173 / PARIGI BINI *et al.*, 1994. 6èmes J. Rech. Cunic., La Rochelle (France) / DALLE ZOTTE *et al.*, 1996. Meat Sci., (in press).
Methods for free lipids: Extraction and gravimetry. The dried muscle or meat sample is extracted by n-hexane or petrol ether or di-ethyl ether (soxhlet), without previous acid hydrolysis. The extract is dried and weighed.
General reference: AFNOR, 1968. Détermination de la teneur en matière grasse libre, NF V 04-403 (EQV ISO 1444), AFNOR, Paris *(France)* / AOAC, 1984. Official methods of Analysis (14th Ed.). Assoc. Offic. Anal. Chem. Washington, DC.
Specific reference: OUHAYOUN, 1978. Thesis, Montpellier.

Lipids (iodine number or value)

Definition: Quantity of iodine absorbed by a unit of weight of any substance.
Interest: Iodine index is a measure of the unsaturated linkages present in fat.
Methods: Chemistry. 1- the contact of well known quantities of lipid sample with iodine allows the addition of halogen in the ethylenic linkages of fatty acids. The iodine number is the difference between introduced and remaining iodine divided by the weight of lipid sample (g/100g). 2- The iodine number can be estimated on the basis of fatty acid composition.
General reference: PRICE & SCHWEIGERT, 1971. The Science of meat and meat products. Freeman & Co., San Francisco.
Specific references: CAMBERO *et al.*, 1991. Meat Sci., **29**, 153 / PARIGI BINI *et al.*, 1992. Zoot. Nutr. Anim., **18**, 173 / CABANES *et al.*, 1995. Viandes Prod. Carnés **16**, 132.

Moisture (content)

Definition: Totality of free and linked water.
Interest: Main component of muscle, complement of dry matter.
Methods: Drying and gravimetry. After the addition of ethanol to the ground muscle or meat, the sample is submitted to heating (60-80°C) up to evaporation of the ethanol and then to drying (103°C ± 2°C) for 4 hours (AFNOR). The heating may be performed without previous addition of ethanol (AOAC). The residue is weighed.
General references: AFNOR, 1968. Détermination de l'humidité, NF V 04-401 (EQV ISO 1442), AFNOR, Paris (France) / ASPA, Commissione Valutazione Alimenti, 1980. Zoot. Nutr. Anim., **6**, 19 / AOAC, 1984. Official methods of Analysis (14th Ed.). Assoc. Offic. Anal. Chem. Washington, DC.
Specific references: OUHAYOUN & DELMAS, 1989. Viandes Prod. Carnés, **10**, 47 / PARIGI BINI *et al.*, 1992. Zoot. Nutr. Anim., **18**, 173.

Myofibre (number per unitary area, diameter and typing)

Definition: Elementary contractile structure of muscle. According to their energy metabolism balance and their contraction rate, muscular fibres are either oxidative slow twitch, oxidative fast twitch or glycolytic fast twitch.
Interest: Variation of muscle characteristics during development depends on the number (precociously determined), the length and diameter of constitutive fibres and their functional and metabolic differentiation. Fibre types conversion during growth is also possible, affected by several treatments.
Methods: Quantitative histology. Fibre typing is performed on serial cross sections of frozen muscle, after specific treatments: azorubin coloration for fibre number and area, immunohistochemistry using monoclonal specific antibodies of heavy chain or ATPase of each slow or fast myosin isoforms for contractile typing,

succinate dehydrogenase (SDH) reaction for metabolic typing. Percentage and mean cross-sectional area of each fibre type is determined in random fields with computerized image analysis.
General references: BROOKE & KAISER, 1970. Arch. Neurol., **23**, 369 / ASHMORE & DOERR, 1971. Exp. Neurol., **31**, 408 / LEFAUCHEUR *et al.*, 1992. Meat Sci., **32**, 267.
Specific references: VIGNERON & BACOU, 1976. J. Anim. Sci., **49**, 985 / ALASNIER *et al.*, 1996. Meat Sci., (in press) / DALLE ZOTTE & OUHAYOUN, 1996. Meat Sci., (in press).

Nitrogen (total)

Definition: Total nitrogen included in proteins, peptids and non-peptidic compounds.
Interest: One of the main components of muscle or meat. May be related to total protein content using a general coefficient (6.25).
Methods: Reference method of Kjeldahl includes 1- a catalyzed mineralization of nitrogen by heating in concentrated sulphuric acid, 2- an alkaline treatment followed by a distillation and a dosage of the produced free NH_3.
General references: AFNOR, 1972. Dosage de l'azote total, NF V 04-407 (EQV ISO 937), AFNOR, Paris (France) / ASPA, Commissione Valutazione Alimenti, 1980. Zoot. Nutr. Anim., **6**, 19 / AOAC, 1984. Official methods of Analysis (14th Ed.). Assoc. Offic. Anal. Chem. Washington, DC.
Specific references: OUHAYOUN & DELMAS, 1983. Ann. Zootech., **32**, 277 / PARIGI BINI *et al.*, 1992. Zoot. Nutr. Anim., **18**, 173 / BATTAGLINI *et al.*, 1994. Ital. J. Food Sci., **2**, 157 / HADDAD *et al.*, 1994. 6èmes J. Rech. Cunic., La Rochelle (France).

Nitrogen (composition)

Definition: Overall total nitrogen includes nitrogen of myofibrillar proteins (myosin, actin, troponin, tropomyosin), sarcoplasmic proteins (enzymes of the energy metabolism, myoglobin), stroma proteins (collagen, reticulin, elastin) and non-proteinic compounds.
Interest: Nitrogen composition is in relation to fibre typing, energy metabolism balance and muscle buffering capacity.
Methods: Chemistry. Nitrogen fractions are separated by differential solubility and quantified according to the Kjeldahl method.
General reference: HELANDER, 1957. Acta Physiol. Scand., Suppl., **141**, 9.
Specific references: VIGNERON, 1973. Ann. Biol. anim. Bioch. Bioph., **13**, 553 / OUHAYOUN & DELMAS, 1983. Ann. Zootech., **32**, 257.

pH

Definition: In meat (a semi-solid compound), the pH is defined as the cologarithm of the H^+ rate of the liquid phase, balanced with the solid phase.
Interest: Immediately after death, pH value is near to neutrality; within a few hours it falls to a stable value (ultimate pH or pH_u), depending on muscle and its energy reserves. Generally, the meat instrumental (colour, water holding capacity) and sensory (juiciness and tenderness) characteristics depend on the rate and intensity of the pH fall.
Methods: pH is most often measured *in situ* using a thin electrode after incision of muscle aponevrosis. The initial pH measure (less than one hour after death) using this system is inaccurate, due to insufficient water disposability; in this case crushing muscle in Na-Iodoacetate 0.005 M is recommended.
General references: DRANSFIELD *et al.*, 1983. Meat Sci., **8**, 79 / KORKEALA *et al.*, 1986. Meat Sci., **18**, 121.
Specific references: OUHAYOUN *et al.*, 1973. J. Rech. Avic. Cunic. Paris (France) / HOFMANN, 1988. Fleischwirtsch., **68**, 67 / BLASCO & PILES, 1990. Ann. Zootech., **39**, 133 / XICCATO *et al.*, 1990. 44 Conv. Naz. S.I.S.Vet., 577 / CABANES *et al.*, 1994. Viandes Prod. Carnés, **15**, 175 / PARIGI BINI *et al.*, 1994. 6èmes J. Rech. Cunic., La Rochelle (France) / DALLE ZOTTE & OUHAYOUN, 1995. Meat Sci., **39**, 395.

Phospholipids (content)

Definition: Esters of fatty acids and alkohols combined with phosphoric acid.
Interest: Phospholipids contribute, with cholesterol and proteins, to the architecture of membranes. While determining nutritive value of meat, phospholipids are also involved in reactions that influence its flavour.

Methods: Chemistry. Extraction and dessication of total lipids. Dosage of phosphorus, through an overnight mineralization in perchloric acid (180°C), colorimetric reaction (100°C) involving hydrazine sulfate and sodium molybdate. The blue color that develops is measured photometrically at 830 nm. A reference scale for P is performed using KH_2PO_4. Phospholipids content is calculated multiplying P content by 25.
General references: FOLCH *et al.*, 1957. J. Biol. Chem., **226**, 497 / BARTLETT, 1959. J. Biol. Chem., **234**, 466.
Specific references: GRIFFITHS *et al.*, 1989. Proc. Nutr. Soc., 48, 5A / ALASNIER *et al.*, 1994. 40th Int. Congress of Meat Sci. Technol., The Hague, The Nederlands / ALASNIER *et al.*, 1996. Meat Sci., (in press).

Sarcomere (length)

Definition: In the myofibre, it is represented by the interval between two Z discs.
Interest: Normal length is about 2 µm in resting muscle. Changes in sarcomere length after death depend on several technological factors, i.e. stunning and *rigor mortis* onset conditions, carcass suspension. It is related to myofibrillar toughness of meat.
Method: Slight crushing of muscle in buffered glutaraldehyde aqueous solution, measuring of sarcomere length by diffraction of a 633 nm laser beam.
General reference: CROSS *et al.*, 1981. Meat Sci., **5**, 261.
Specific reference: OUHAYOUN *et al.*, 1990. 5èmes J. Rech. Cunic. Paris (France).

Smell

Definition: Olfactive sensation resulting from volatile emanations of meat.
Interest: Component of flavour (see above).

Tenderness

Definition: Meat property which expresses the easiness of chewing.
Interest: Among the main subjective criteria of meat quality. The meat tenderness is closely related to the characteristics of its structural components such as the extent of ageing, the length of the sarcomeres, pH and water retention in the myofibrillar structure, the amount of collagen, its cross-linking state and hence its thermostability, and the spatial distribution of the connective tissue.
Methods: A panel of experts quantifies the tenderness according to scale levels (from 6 to 100).
General references: AMSA, 1978. Guidelines for cooking and sensory evaluation of meat. National Livestock and Meat Board. Chicago, Il, 25 p. / CROSS *et al.*, 1978. Food Technol., **32**, 48 / AFNOR, 1991. Contrôle de la qualité des produits alimentaires. Analyse sensorielle. Recueil de normes françaises, 4ème édition. AFNOR-DGCCRF, Paris La Défense (France), 326 p.
Specific references: CABANES *et al.*, 1994. Viandes Prod. Carnés, **15**, 175 / XICCATO *et al.*, 1994. 40th Int. Congress of Meat Sci. Technol., The Hague, The Nederlands / DALLE ZOTTE *et al.*, 1995. Coniglicoltura, **6**, 33.

Toughness

Definition: Strength of a piece of muscle or meat to any deformation and particularly to penetration or shearing.
Interest: The shear force value partially explains the tenderness (see above) and it is used in parallel with a sensory tenderness test to determine the acceptability thresholds for meat.
Methods: Rheology. The most widely used (78%) mechanical method is the Warner-Bratzler test. Shear force value is measured on cooked samples (core temperature 80°C) after cooling. Meat cylinders (12.5 mm diameter) are removed from each sample and each cylinder is sheared perpendicular to the muscle fibres three times by a Warner-Bratzler cell mounted on an INSTRON 1140 texturometer. On rabbit, the main difficulty is to obtain samples of sufficient size, precise location and uniform geometry (diameter, length).
General references: WARNER, 1928. In: Lepetit & Culioli, 1994. Meat Sci., **36**, 203 / BOCCARD, 1976. In: Fisher *et al.*, 1976. Criteria and methods for assessment of carcass and meat characteristics in beef production experiment, CEE, EUR 5489, 269 / SINDIC *et al.*, 1993. Viandes Prod. Carnés, **4**, 95.
Specific references: BATTAGLINI *et al.*, 1994. Ital. J. Food Sci., **2**, 157 / XICCATO *et al.*, 1994. 40th Int. Congress of Meat Sci. Technol., The Hague, The Nederlands.

Water holding capacity

Definition: In meat, about 8% of water is closely linked to proteins and is not concerned with exudation; the remainder is more or less linked and its release depends on applied treatment.
Interest: Technological criterion closely related to meat juiciness and tenderness.
Methods: Several methods including cooling and chilling (drip loss, chilling loss), pressure (filter paper loss, pressure loss), dry or steam heating (heat loss, cooking loss, baking loss, boiling loss, melting loss) or centrifugation (i.e. 17.000 rpm for 30 mn), are used.
General references: GRAU & HAMM, 1957. Z. Lebensm. Unters. Forsh., **105**, 446 / HONIKEL, 1987. Recommendation of standardized methods. In: Tarrant *et al.*, 1987. Evaluation and control of meat quality in pigs, 129. Martinus Nijhoff Pub., Dordrecht / DUMONT & HUDZIK, 1983. Viandes Prod. Carnés, **n° spécial**, 55 / GAULT, 1985. Meat Sci., **15**, 15 / BARGE *et al.*, 1992. 38th Int. Congress of Meat Sci. Technol., **2**, 233 / SINDIC *et al.*, 1993. Viandes Prod. Carnés, **4**, 95.
Specific references: OUHAYOUN & DELMAS, 1989. Viandes Prod. Carnés, **10**, 47 / BATTAGLINI *et al.*, 1994. Ital. J. Food Sci., **2**, 157 / CABANES *et al.*, 1994. Viandes Prod. Carnés, **15**, 175 / XICCATO *et al.*, 1994. 40th Int. Congress of Meat Sci. Technol., The Hague, The Nederlands.

Acknowledgements to contributors - The present paper takes into account the advice of 16 researchers coming from 5 countries among the 120 to whom a manuscript had been proposed by OUHAYOUN in 1994: L. MAERTENS (Belgium), M. RISTIC (Germany), S. FEKETE (Hungary), C. CASTROVILLI (Milano, Italy), G.M. CHIERICATO, U. FILOTTO, R. PARIGI BINI, C. RIZZI, G. XICCATO (Padova, Italy), G. PACI, G. PREZIUSO (Pisa, Italy), M. BERNARDINI BATTAGLINI, C. CASTELLINI (Perugia, Italy), G. MASOERO (Torino, Italy), S. NIEDZWIADEK (Poland), S.D. LUKEFAHR (Texas).