RELATIONSHIP BETWEEN PHYSICO-CHEMICAL MEASUREMENTS AND VEAL MEAT TENDERNESS DURING AGEI

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Introduction

In veal meat, despite the role of colour as an important factor determining the value of carcasses, tenderness, juiciness and cooking lo are also very important criteria of quality (Guignot *et al.*, 1992). Pearson (1994), refers to the following factors affecting meat tenderne exercise, sex, breed, marbling, fat covering, conformation, type of muscle, onset of rigor mortis, cold-shortning, thaw-shortning, ageing a electrical stimulation. As refered by Smulders *et al.* (1991), connective tissue, fat and myofibrillar protein matrix are the main components determine the tenderness of meat. The contribution of myofibrillar proteins to toughness is largely determined by *rigor mortis* and *post-mor* ageing process (Smulders *et al.*, 1991). The mechanism of improvement of meat tenderness during *post-mortem* storage at refrigera temperatures remains controversial. However, proteolysis of myofibrillar proteins may have an important role. In contrast to lysosom cathepsins and the multicatalytic proteinase complex (MCP), substancial evidence suggests that calpains (mainly μ-calpain) are the prim system responsible for *post-mortem* proteolysis (Koohmaraie, 1996).

The aim of the present work was to determine the influence of storage of veal meat at refrigeration temperature in its quality and t relation between tenderness assessed objectively and subjectively and some variables that have been proposed as an influence of m tenderness: sarcomere length, myofibrillar fragmentation, myofibrillar solubility, intramuscular fat and cooking loss.

Materials and Methods

In this study, males (n=23) of a portuguese autochthonous breed (Maronesa) with 8-11 months and carcasses weight of 100-164 k were used. Carcasses were chilled 1 h at 0°C, 4 m/s and kept at 1°C until 24 h *post-mortem*. At 28 h *post-mortem longissimus* was excise (between 8th rib and 2nd lumbar vertebra) and cut in three parts (± 600 g). One part of the muscle was used for meat characterization at day *post-mortem* and the two others were vacuum packed and aged at 2±2°C until 6 and 13 days *post-mortem*.

The pH was measured directly in the muscle using a combined glass electrode with a pH-Meter Crison 2002.

For determination of sarcomere length, about 200 mg of muscle were fixed in a solution of 2% glutardialdehyde and 0.2M sucrose 0.2M phosphate buffer pH 7.1 (Honikel *et al.*,1981). Bundles of 3-4 fibers were removed of the fixed muscle tissue and the length of consecutive sarcomeres was measured (30 groups of 10 sarcomeres for each sample) on a optic microscope (x 1000) using phase contr (Jaime *et al.*,1993).

Myofibrillar fragmentation index (MFI) was determined in frozen samples as described by Culler *et al.* (1978). After determination protein concentration of the suspension by the biuret method (Gornall *et al.*, 1949), the suspension was diluted with 0.02 M potassiu phosphat buffer (pH 7.0) to 1.0 mg/ml protein concentration. The exact protein concentration was determined using the micro-biuret metho (Itzhaki and Gill, 1964 as cited by Clark, 1984) and the suspension of myofibrils diluted to 0.5 ± 0.05 mg/ml. MFI is the value of absorbance myofibrillar suspension, measured at 540 nm multiplied by 200. Myofibrillar protein solubility (MPS) was determined in a high ionic strengt buffer at pH 7.0 (0.4 M NaCl, 1 mM EDTA, 19 mM KH_2PO_4, 31 mM Na_2HPO_4 and 1 mM NaN_3) for the determination of MPS pH7.0 or a pH 5.5 (0.4 M NaCl, 1 mM EDTA, 100 mM citric acid and 1 mM NaN_3) for determination of MPS pH5.5 according to Claeys *et al.* (1994). The protein concentration was determined in the supernatant by the biuret method (Gornall *et al.*, 1948) and results expressed as mg solubilized protein / g muscle.

Intramuscular fat was determined by extraction in a soxhlet apparatus using petroleum ether (ISO, 1973). The Cooking loss was determined in meat samples heated to an internal temperature of 70°C and was expressed as percentage of loss by heating based on the initia weight. After measurement of cooking loss the samples were used for determination of Warner-Bratzler shear force (WBSF) measured in 10 12 sub-samples with ±1 cm^2 cross section and 4-5 length with fibres perpendicular to the direction of the blade attached to a Stevens QTS 2 apparatus.

For sensory evaluation ±1.5 cm thick steaks were covered with an aluminium foil and heated in a double side contact grill (230°C) to a internal temperature of 70°C. To a semi-trained panel of 6 members were asked to rank the meat on a 9-point scale: for tenderness (1 = estremely tough, 9 = extremely tender), juiciness (1 = estremely dry, 9 = extremely juicy) and flavour (1 = estremely undesirable, 9 = extremely desirable). Data analisys was performed with Systat 5.0. Tukey HSD was used to locate differences between means.

Results and Discussion

Table 1 shows the means and standard deviation of the parameters study in the three days *post-mortem*. The results show a significant increase of tenderness of meat from day 1 to day 6, evaluated by panel ($P < 0.05$) and by WBSF ($P < 0.001$). A period of ageing longer than 6 days did not increase the tenderness evalueted by both methods. It was also observed that the tenderness increase linearly whith ultimate pH (measured at 28 h *post-mortem*) and significant ($P < 0.001$) correlations were found between the pH_{28} and the values of WBSF and panel tenderness to the three days *post-mortem* (Table 2). The significant ($P < 0.001$) correlation of the cooking loss and juiciness with tenderness assessed objectively and subjectively, may partialy explain the increase in tenderness with pH_{28} (Guignot *et al.*,1992). The strong correlation found between WBSF and panel tenderness (-0.852, -0.801 and -0.881 at 1, 6, and 13 days *post-mortem*) suggest that it is sufficiently correlated to justify the use either one or other for assessing veal meat tenderness.

Despite some authors have found an increase of toughness with decrease of sarcomere length (Bouton *et al.*, 1973), other works do not support this relation (Culler *et al.*, 1978; O'Halloran *et al.*, 1994). In this work, the sarcomere length was not significantly ($P>0.05$) correlated with WBSF and sensorial tenderness, excluding curiously at day 6 and only between sarcomere length and WBSF (Table 2).

Various works showed that MFI increases with ageing of meat (Olsson *et al.*, 1976: Olsson and Parrish, 1977; Heinz *et al.*, 1994). This increse of MFI with ageing seems to be related to the phenomenon of myofibrils breaking into shorter segments at or near the Z-disk during *post-mortem* storage of meat (Olsson *et al.* 1976). A high negative correlation betwen MFI and WBSF has been documented and, as refered by Culler *et al.* (1978) the MFI is a potential method for identifying tough and tender beef carcasses. These results show that MFI increases with ageing, although between day 6 and day 13 this increase was not statistically significantly ($P > 0.05$). At day 1 *post-mortem* the MFI is strongly correlated with WBSF and with panel tenderness, (-0.676 and 0.671 respectively) but, at day 6 and 13 *post-mortem* the relationship was lower. These results were partially according with Shackelford *et al.* (1991) who found correlation coefficients -0.91, -0.74, -0.63 and -0.40 between WBSF and MFI in beef *longissimus* dorsi at 1, 3, 7 and 14 days *post-mortem* respectively.

Myofibrillar protein salt solubility at pH 7.0 and pH 5.5 incrased significantly ($P < 0.05$) from day 1 to day 6. Claeys *et al.* (1994), have found a significantly negative correlation ($P < 0.01$) between MPS at pH 7.0 and at pH 5.5 with WBSF in *longissimus thoracis* muscle three days *post-mortem*, wich suggests that myofibrillar protein solubility is the result of proteolytic breakdown of key proteins that causes minor but important changes in the myofibrillar meat structure and promotes tenderization. In this study it was observed a significant ($P< 0.001$ at 1 and 6 days, $P < 0.01$ at 13 days *post-mortem*) correlation between MPS at pH 7.0 and the tenderness assessed by both methods. However, no significantly ($P > 0.05$) correlation was found for the MPS at pH 5.5. It is to remark that, in day 1, the MFI and MPS pH 7.0 were strongly

TABLE 1

Means and standard deviations (sd) of various parameters measured at 1, 6 and 13 days *post-mortem*.

	1	6	13
	Mean ± sd	Mean ± sd	Mean ± sd
pH	$6.08^{a} \pm 0.36$	$6.09^{a} \pm 0.36$	$6.01^{a} \pm 0.32$
Sarcomere length (μm)	$1.66^{a} \pm 0.21$	$1.59^{a} \pm 0.17$	$1.57^{a} \pm 0.13$
WBSF (Kg/cm^2)	$12.39^{a} \pm 3.00$	$8.75^{b} \pm 3.27$	$8.67^{b} \pm 3.30$
MFI	$79.28^{a} \pm 16.51$	$118.73^{b} \pm 15.37$	$124.67^{b} \pm 12.31$
MPS pH 7.0 (mg/g)	$26.86^{a} \pm 10.51$	$32.41^{b} \pm 8.01$	$33.71^{b} \pm 8.55$
MPS pH 5.5 (mg/g)	$19.37^{a} \pm 3.71$	$21.90^{b} \pm 3.22$	$21.51^{b} \pm 2.90$
Cooking loss (%)	$14.36^{a} \pm 3.27$	$14.67^{a} \pm 4.47$	$15.74^{a} \pm 3.89$
Panel tenderness	$5.28^{a} \pm 1.30$	$6.21^{b} \pm 1.29$	$6.12^{b} \pm 1.25$
Flavor	$5.51^{a} \pm 0.94$	$5.81^{a} \pm 0.80$	$5.70^{a} \pm 0.78$
Juiciness	$5.04^{a} \pm 1.02$	$5.70^{a} \pm 0.78$	$5.13^{a} \pm 1.21$

In the same row, means with different superscripts are significantly different ($P<0.05$).

TABLE 2

Simple correlations of various parameters whith WBSF (above) and panel tenderness (below) at 1, 6 and 13 days *post-mortem*.

	1	6	13
pH_{28}	-0.832***	-0.702***	-0.784***
	0.779***	0.710***	0.812***
Sarcomere length	-0.109^{ns}	-0.551**	-0.230^{ns}
	-0.004^{ns}	0.280^{ns}	0.203^{ns}
MFI	-0.676***	-0.521*	-0.506*
	0.671***	0.354^{ns}	0.435*
MPS pH 7.0	-0.655***	-0.825***	-0.595**
	0.701***	0.760***	0.552**
MPS pH 5.5	-0.220^{ns}	0.207^{ns}	0.294^{ns}
	0.474*	-0.036^{ns}	-0.185^{ns}
Intramuscular fat	0.055^{ns}	0.097^{ns}	0.130^{ns}
	0.033^{ns}	-0.208^{ns}	-0.226^{ns}
Cooking loss	0.791***	0.665***	0.741***
	-0.844***	-0.642***	-0.764***
Panel tenderness	-0.852***	-0.801***	-0.881***
Flavor	-0.566**	-0.606**	-0.412^{ns}
	0.741***	0.684***	0.609***
Juiciness	-0.784***	-0.742***	-0.749***
	0.876***	0.803***	0.868***

ns, not significant; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

correlated ($P < 0.001$) with WBSF and with sensorial tenderness but, at day 6 the MPS pH 7.0 showed a better relationship with the WBSF (-0.825) and with the sensorial tenderness (0.760) than MFI (-0.521 and 0.354 for the WBSF and sensorial tenderness respectively). This suggests that at day 6 *post-mortem* MPS pH 7.0 is a better predictor of tenderness than MFI.

As it is shown (Table 2), intramuscular fat is not relationed with tenderness. Usually, higher intramuscular fat contents are associated with increased tenderness, possibly because: per volume unit of muscle, less tissue and fibrillar elements are present (Smulders *et al.*, 1991); fat promotes salivary flux and easily chewing and facilate the separation of fibres bundles during chewing (Wood, 1993). The low mean content of intramuscular fat found (1.9%) was probably the reason of negleted relationship between intramuscular fat and tenderness.

The losses of moisture determined as cooking loss did not change with the time of storage as previously showed by Honikel (1987) in pig meat. Flavour and juiciness also showed no significant differences with storage of meat.

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