



Effect of ageing time on consumer-perceived quality of Italian Simmental beef

Edi Piasentier, Massimo Marangon, Micaela Morgante,
Roberto Valusso, Luisa Antonella Volpelli

Dipartimento di Scienze della Produzione Animale. Università di Udine, Italy

Corresponding author: Prof. Edi Piasentier. Dipartimento di Scienze della Produzione Animale. Via San Mauro 2, 33010 Pagnacco (UD), Italy - Tel. +39 0432 650110 - Fax: +39 0432 660614 - Email: edi.piasentier@dspa.uniud.it

Paper received October 21, 2003; accepted January 27, 2004

ABSTRACT

The aim of the experiment was to provide an objective indication on the optimal ageing time of meat from Italian Simmental (IS) young bulls, the most important commercial category of the breed. The research was carried out on 10 young bulls slaughtered at the average weight of 688 kg (SE: 7.3 kg). The right side of each carcass was stored for 7 days and the left one for further 7 days, at normal refrigeration temperatures. At the end of the ageing period, the sides were sampled at the loin for meat pH, color, cooking loss and shear force measurement. A central location, affective test involving 74 consumers was carried out to measure the degree of liking for grilled beef aged 7 or 14 days.

The pH and color parameters were not significantly affected by the duration of post-mortem storage, while cooking loss increased (31.4 vs 32.6 %; $P < 0.05$) and shear force values diminished (56.7 vs 46.8 N; $P < 0.01$) when ageing time increased from 7 to 14 days. The degree of liking by the untrained respondents for the two types of cooked meat was different, considering that consumers gave the highest hedonistic scores to beef aged 14 days. Tenderness was the sensory attribute that allowed the best discrimination between beef stored for periods of different length. In fact, while the difference between 14-day-aged and 7-day-aged beef for flavour ratings (7.0 vs 6.9) did not reach the threshold of significance, the former meat was perceived as significantly finer than the latter regarding tenderness (6.5 vs 5.6; $P = 0.01$) and marginally preferred in overall terms (6.9 vs 6.5; $P = 0.07$). The classification test, carried out at the end of the quantitative test by asking consumers to select from a list the most appropriate attributes describing the stimuli associated with meat consumption, confirmed the effectiveness of texture attributes in ranking different-aged beef acceptability. In fact, the number of ticks reported for chewiness and juiciness descriptors were different for the two types of meat: the 14-day-aged beef was perceived as easier to chew (57 vs 34 ticks) and juicier (42 vs 24) than the shortest-aged beef. Ageing for 14 days should be recommended as a process control point for the beef industry to improve consumer acceptance of IS young bull beef.

Key words: Ageing, Italian Simmental bulls, Meat quality, Consumer test

RIASSUNTO

EFFETTO DELLA DURATA DELLA FROLLATURA SULLA PERCEZIONE DI QUALITÀ DEL CONSUMATORE NEI CONFRONTI DELLA CARNE DI PEZZATA ROSSA ITALIANA

Lo scopo della ricerca è fornire indicazioni oggettive sulla durata ottimale della frollatura della carne di vitellone di Pezzata Rossa Italiana, la più importante categoria commerciale della razza. Per cogliere il miglioramento complessivo della piacevolezza della carne all'aumentare della durata della frollatura, è stata effettuata un'analisi sensoriale di tipo edonistico che, esprimendo una valutazione di gradevolezza basata sul giudizio dei fruitori finali del prodotto, rappresenta un test attendibile e trasparente, affidabile sia per l'industria alimentare che per i consumatori.

La prova è stata effettuata con 10 vitelloni di 540 giorni (ES: 8,5 giorni) e 688 kg (ES: 7,3 kg). La mezzena destra di

ciascuna carcassa è stata conservata per 7 giorni e quella sinistra per ulteriori 7 giorni, alla normale temperatura di refrigerazione. Al termine del periodo di frollatura, le mezzene sono state campionate in corrispondenza del muscolo longissimus thoracis, per le misure di pH, colore, perdite di cottura e resistenza al taglio. Inoltre è stato effettuato un test sensoriale di tipo affettivo, in locazione esterna, che ha coinvolto 74 consumatori, per misurare il grado di piacevolezza della carne grigliata, frollata 7 o 14 giorni.

Il pH e il colore della carne frollata 7 o 14 giorni non sono risultati significativamente diversi, mentre durante la seconda settimana di conservazione sono aumentate le perdite di cottura (31,4 vs 32,6 %; $P < 0,05$) ed è diminuita la resistenza al taglio (56,7 vs 46,8 N; $P < 0,01$) della carne. Il grado di soddisfazione espresso dai consumatori non addestrati mangiando i due tipi di carne è stato diverso, avendo ricevuto quella frollata più a lungo i punteggi edonistici più elevati. La tenerezza è stato l'attributo sensoriale che meglio ha consentito di discriminare le carni con diversa lunghezza di frollatura. Infatti, mentre la differenza di sapore fra carne frollata 14 e 7 giorni non ha raggiunto la significatività statistica (7,0 vs 6,9 punti), la carne conservata più a lungo è stata percepita come più tenera (6,5 vs 5,6 punti; $P = 0,01$) e leggermente migliore in termini di piacevolezza generale (6,9 vs 6,5; $P = 0,07$). Il test di classificazione, condotto al termine di quello quantitativo chiedendo ai consumatori di selezionare da una lista gli attributi più appropriati per descrivere gli stimoli associati al consumo della carne, ha confermato l'efficacia degli attributi strutturali nella valutazione dell'accettabilità della carne a diversa frollatura. Infatti, il numero di scelte ottenuto dagli attributi di masticabilità e succulenza è risultato statisticamente diverso per i due tipi di carne: quella frollata per 14 giorni è stata percepita come più facile da masticare (57 vs 34 scelte) e più succulenta (42 vs 24 scelte).

Pertanto, si può concludere raccomandando l'adozione di un periodo di frollatura di 14 giorni, per esaltare l'accettabilità dei consumatori nei confronti della carne di vitellone Pezzato Rosso Italiano.

Parole chiave: Frollatura, Vitellone Pezzato Rosso Italiano, Qualità della carne, Test di consumo

Introduction

The processes that affect tenderness, which is an important part of meat acceptability, are as well known as the variability of tenderness post-mortem evolution (Zamora *et al.*, 1996). Ageing, i.e. the practice of storing meat at normal refrigeration temperatures for some time after slaughter, is the simplest and best documented method of improving the inconsistency of meat tenderness at the consumer level (Koochmaraie, 1996). In spite of this, owing to the costs of storage and refrigeration and the weight losses for water evaporation and exudation, the majority of beef produced is aged only for the duration of distribution and retailing, which may be as short as three days after slaughter.

The Italian Simmental (IS) Breeders' Association (ANAPRI), with the purpose of promoting IS beef on the basis of quality, is examining a quality assurance system which manages quality along the entire production chain. One of the critical points is ageing, the duration of which should suffice for the meat to reach an acceptable tenderness, according to consumer expectations, in a commercially reasonable period of time.

The aim of the experiment is to provide objective indication on the optimal ageing time of meat from IS young bulls, the most important commercial category of the breed. To account for all the improvement in beef palatability when ageing time increased it was decided to use the consumer testing, which allowed a reliable, transparent, system of testing meat that would engender confidence in both the beef industry and consumers. The same would also allow the final assessment of palatability to be determined by the target consumer market for the product (Thompson, 2002).

Material and methods

Animals

The research was carried out on 10 young bulls of IS breed, randomly chosen among the bulls subjected to performance test at the IS National Association Genetic Centre and destined to slaughtering. The animals were reared on slatted-floor multiple boxes and slaughtered at the age of 16-20 months. The mean values of age and live weight, individually recorded the day before slaughtering, are summarized in Table 1.

Table 1. *In vivo* and carcass characteristics of Italian Simmental young bulls.

Item		mean	SE
Age	days	540	8.5
Live weight	kg	687.5	7.29
Carcass weight	"	395.2	3.90
Dressing percentage	%	57.5	0.63
Conformation score ¹		3.7	0.16
Fatness score ²		2.5	0.18
pHu		5.48	0.028

¹ Community scale for the classification of carcasses of bovine animals (ECC, 1981a; 1981b; 1991).
Conformation score: from S (superior)=6 to P (poor)=1.

² As above. Fatness score: from 5 (very abundant) to 1 (very low).

Slaughtering conditions and carcass characteristics

All bulls underwent similar transport (approx. 1.5 hours) and waiting conditions (1-2 hours) before slaughtering at an EU-licensed abattoir, using conventional commercial procedures, without carcass electrical stimulation. After chilling at 4°C for 24 hours, the carcasses were weighed and scored for conformation and fatness, following the EUROP standardized classification (EEC, 1981 a; 1981 b; 1991). At the same time, the ultimate pH (pH_u) was measured three times, on the longissimus thoracis muscle, between the 11th and 12th thoracic vertebrae by a glass piercing electrode (Crison 52-32) connected to a pH-meter. As summarized in Table 1, the carcass weight and its incidence on the weight at slaughter, the carcass conformation grade (between U and R) and fatness score (between 2 and 3) of the 18-month-old IS bulls were in accordance with those previously reported for the same category of animals, produced under the same conditions (Piasentier *et al.*, 2003). The mean pH at 24 hours after slaughtering was 5.48, which is a value comprised in the normal commercial range, the same as 5.65, the highest pH_u recorded.

Meat ageing and sampling

The right side of each carcass was then stored for 6 days and the left one for further 7 days, at normal refrigeration temperatures (0-4°C), all the time hanging by the Achilles tendon. At the end of

the ageing period, i.e. respectively 7 and 14 days after slaughtering, both sides were quartered by pistol style cut yield and their hind quarter sampled at the loin (muscle *longissimus thoracis*, 9th - 11th rib section, LT), by cutting three (right side, 7 days of ageing) or two (left side, 14 days of ageing) three-centimeter thick chops.

The first steaks from both, the 7- and 14-day-aged LT muscle, were immediately vacuum frozen and stored at -20°C for an average period of 6 months prior to consumer test.

Beef pH and physical properties

On the second section of both, the 7- and 14-day-aged LT, meat pH was measured as above and color was evaluated, according to CIE L*, a*, b* color system, after a 1-hour blooming period at normal refrigeration temperatures, by a Minolta CM-2600d Spectrophotometer (Minolta Camera, Osaka, Japan) with D65 illuminant.

The same sections were then used to measure water loss (in a 75°C-water bath for 20 min.; ASPA, 1996) and shear force, on the cooked sample, using a Warner-Bratzler device with a triangular shaped hole in the shear blade, mounted on an Instron 4301 (Instron Ltd., High Wycombe, United Kingdom) universal testing machine; the measurement was recorded as the peak yield force in N, required to shear, at a 100 mm/min crosshead speed, perpendicularly to the direction of the fibers, three cylindrical cross-section, 10 mm diameter x 30 mm length, replicates from each sample.

Beef chemical composition

The third steak from the right side was quickly frozen under vacuum and stored at -20°C to be analyzed for its proximate composition (ASPA, 1996). The chemical composition of beef, as summarized in Table 2, was in accordance with that previously reported for the same category of animals, produced under the same conditions (Piasentier *et al.*, 2003).

Consumer test

A central location, quantitative affective test was carried out to measure the consumer degree of liking for grilled beef aged either 7 or 14 days, by examining three sensory attributes: flavour, tenderness and overall liking (Meilgaard *et al.*, 1991). Every untrained respondent was requested to score each attribute on an intensity scale, with values ranging from 1 (very bad) to 9 (excellent).

At the end of the quantitative test, the consumers were involved in a classification test (Meilgaard *et al.*, 1991). The respondents were asked to select, by ticking from a provided list, the most appropriate attributes describing the stimuli associated with meat consumption. Descriptors were previously selected looking at a few simple, widely understood attributes, useful in getting consumers to explain the organoleptic basis of their preference for beef aged for periods of different length. The proposed word list included alternatives that are mutually exclusive and exhaustive - beefy odour and barnyard odour, juicy and dry, easy to chew and difficult to chew- without the introduction of any relationship between the attributes faced on the same parameter. The results were reported for each attribute as the number of consumers that ticked it.

Two meat samples prepared from LT muscle steaks (see above), one for each ageing time and both obtained from the same animal, were served on the same plate and consumed, and the respondents were asked to test them in a pre-ordinate order, indicated on the ballot and provided to allow a balanced design (one half of consumers had to start with one type first; the other with the second). Steaks were thawed at 4°C overnight 24 h before the test. Meat was cooked on a grill at 200°C until it reached 70°C of internal temperature, which was monitored by an internal thermocouple, and immediately served.

The 74 consumers involved in the sensory evaluation were adult women and men, mainly (86.5%) aged between 25 and 65 and came from Friuli Venezia Giulia, a North Eastern Italian region. Holders of high educational levels – degree or high school certificate – in the proportion of 67.6%, they belonged to three job categories, approx. equally numbered: entrepreneur – farmer and breeder included – retailer or independent professional; employee or worker; pensioner, housewife or student. They were customary meat eaters, i.e. consumed meat more than once a week in 83.8% of cases, and bought mainly retailed meat (73.9%) at butcher shops or in supermarkets (70.3%), following this order of decreasing preference: beef, cured meat, pork, poultry and game (mostly in restaurant); horse, lamb and goat meat were appreciated and eaten only by a small number of people.

Statistical analysis

Beef physical data and consumer responses for each sensory attribute were compared using a paired t-test, while the frequency of selection of each attribute were analyzed by using a χ^2 test.

Table 2. Proximate analysis of beef from *longissimus thoracis* muscle of Italian Simmental young bulls.

Item		Mean	SE
Moisture	% wet weight	72.6	1.25
Crude protein	"	21.9	0.42
Ether extract	"	4.35	0.920
Ash	"	1.07	0.011

Table 3. pH and physical properties of beef from *longissimus thoracis* muscle of Italian Simmental young bulls, as affected by ageing time.

		Ageing time		SE ¹
		7 days	14 days	
pH		5.66	5.65	0.024
Colour:	L*	50.3	51.0	0.90
	a*	12.0	12.6	0.80
	b*	4.88	4.76	0.242
Cooking loss	%	31.4 ^a	32.6 ^b	0.52
Warner-Bratzler shear force	N	56.7 ^B	46.8 ^A	3.06

¹ SE of the paired difference.

^{A,B} Means in the same row with different superscripts differ significantly ($P \leq 0.01$).

^{a,b} Means in the same row with different superscripts differ significantly ($P \leq 0.05$).

Results and discussion

pH and physical characteristics of aged meat

The effects of ageing time on pH and physical characteristics of beef are reported in Table 3. Comparing the values of pH_u given in Table 1 with those of Table 3, a significant ($P < 0.01$) and expected (Gašperlin *et al.*, 2001) increase of pH can be observed between aged and non aged meat, likely due to hydrolysis of proteins to amino acids. However, after the first week of ageing, the pH showed a steady state around 5.65.

Color parameters (L*, a*, b*), like pH, were not significantly changed by ageing time, even if color was slightly lighter and redder in the most aged samples. These results were in accordance with those of Gašperlin *et al.* (2001) but disagree with Boakye and Mittal's (1996) conclusion that time of ageing affects all the instrumental parameters of beef color. The time of blooming may have been insufficient for a deeper oxygenation of the most aged meat, which would have allowed easier accessibility of oxygen to myoglobin (Gašperlin *et al.*, 2001).

By contrast, the duration of post-mortem storage affected both meat cooking loss and shear force values. The cooking loss increased (31.4 vs 32.6 %) and the shear force values diminished (56.7 vs 46.8 N) in meat when ageing time increased from 7 to 14 days. An increase in cooking loss upon ageing has also been reported by other

authors (Boakye and Mittal, 1993; Purchas *et al.*, 1999). Bertram *et al.* (2004) found that this rise was determined by changes in the water-holding properties of cooked meat during ageing, due to an alteration towards a more homogeneous matrix of the morphology of macromolecules, which is responsible for the binding of water.

The decrease in the resistance to shear in cooked meat with ageing has been extensively documented (Dransfield, 1996; Geesink *et al.*, 1995; Hwang and Thompson, 2001; Jung *et al.* 2000; Palka, 2003; Silva *et al.*, 1999; Wheeler and Koohmaraie, 1994) and it is known that the post-mortem storage changes in shear force values of cooked meat vary greatly from individual to individual (Koohmaraie *et al.*, 2002).

Sensory analysis

The sensory ratings from consumer testing, aimed at evaluating the effect of ageing length on beef palatability, are reported in Table 4. The degree of liking by the untrained respondents for the two types of cooked meat was different, since consumers gave the highest hedonistic scores to beef aged 14 days. Tenderness was the sensory attribute which allowed the best discrimination between beef stored for periods of different length. In fact, while the difference between 14-day-aged and 7-day-aged beef for flavour ratings (7.0 vs 6.9) did not reach the threshold of significance, the former meat was perceived as significantly finer than

Table 4. Consumer preferences for beef from *longissimus thoracis* muscle of Italian Simmental young bulls, as affected by ageing time.

	Ageing time		SE ¹
	7 days	14 days	
Flavour	6.9	7.0	0.26
Tenderness	5.6 ^A	6.5 ^B	0.35
Overall liking	6.5 ^a	6.9 ^b	0.26

¹ SE of the paired difference.

^{A,B} Means in the same row with different superscripts differ significantly ($P \leq 0.01$).

^{a,b} Means in the same row with different superscripts differ at the significance of $P = 0.07$.

the latter regarding tenderness (6.5 vs 5.6; $P = 0.01$) and marginally preferred in overall terms (6.9 vs 6.5; $P = 0.07$).

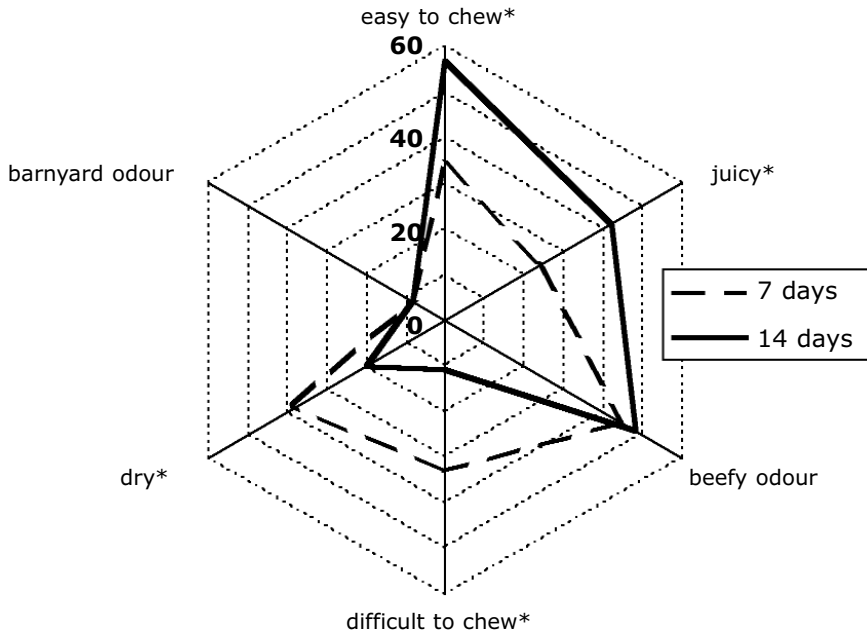
These findings are in accordance with other previous sensory results from panel tests (Campo *et al.*, 1999; Miller *et al.*, 1997; Sherbeck *et al.*, 1995), which showed how, extending beef post-mortem ageing period, trained-assessor sensory values for tenderness improved. Moreover, the affective test outcomes demonstrated that the prolongation of the ageing period from one to two weeks resulted in a detectable increase of beef tenderness liking by typical consumers of the product.

The same did not happen for the liking of flavour, the intensity of which was expected to increase throughout ageing time (Miller *et al.*, 1997), as a consequence of the development of flavour precursors, due to the formation of many peptides and their reaction with other compounds (MacLeod, 1998). It is possible that 7 days may have been too short an extension of ageing period for 7-day-aged and 14-day-aged IS young bull beef to develop and acquire different flavour sensory characteristics perceivable by untrained consumers. In fact, as shown by Campo *et al.* (1999), flavour compounds were related to the final post-mortem phase of a three-week storage period. Moreover, by comparison with the sensory assessment of meat made by taste panelists, skilled in scoring the specific attributes of eating quality, tests by untrained consumers have a larger variance (Thompson, 2002) and thus the capability to detect only ample differences of preference between types of meat.

The results of attribute selection, carried out as a part of the consumer test in the endeavor to better understand the reasons of meat preference, are reported in Figure 1. There, the number of ticks for the mutually exclusive attributes regarding the same parameter are plotted on the opposite halves of the same line, to allow an easy evaluation of consumers' answers consistency. The classification test confirmed the effectiveness of texture attributes in ranking beef acceptability. In fact, the number of ticks reported for chewiness and juiciness descriptors were different for the two types of meat, which were both appreciated because they had a normal beefy odour (45 vs 48 ticks, respectively for 7-day-aged and 14-day-aged beef) and no barnyard odour off-note (8 vs 8). The 14-day-aged beef, preferred for its tenderness and characterized by lower shear values, was also perceived as easier to chew (57 vs 34 ticks) than the shortest-aged beef, which, in turn, was confirmed as more difficult to masticate (11 vs 33).

Moreover, the longest-aged meat obtained a higher frequency of selection for juiciness (42 vs 24 ticks), confirmed by a lesser frequency of dryness (20 vs 38), than the 7-day beef. These texture attributes were in accordance with the higher cooking loss observed in the 14-day beef and the related changes of the water-holding properties hypothesized for the cooked meat. An improvement in juiciness was also observed by Miller *et al.* (1997) who found that ageing steaks for 14 days enhanced both initial and sustained juiciness, compared with steaks aged 7 days, while Campo *et al.* (1999) showed a different evolution of this

Figure 1. Sensory profile of cooked beef aged 7 or 14 days, from a classification test involving 74 consumers.
 (*: $P \leq 0.05$ of the difference between thesis in the frequency of selection of meat attribute).



attribute along ageing, depending on the breed group.

Study funded by the research contract DSPA-ANAPRI, 2001-2002.

Conclusions

The textural improvement of beef throughout ageing, objectively measured by shear force, was clearly perceived by target consumers, who preferred beef when aged for 14 days instead of 7 days in terms of both tenderness and overall liking, since it was classified easier to chew and juicier. Thus ageing for 14 days should be recommended as a process control point for the beef industry to improve consumer acceptance of IS young bull beef.

The authors gratefully acknowledge the director and technicians of Italian Simmental Breeders' Association (ANAPRI) and its National Genetic Centre, and Colomberotto slaughterhouse, for the co-operation in animal and sample procurement.

REFERENCES

- ASPA, 1996. Metodiche per la determinazione delle caratteristiche qualitative della carne. Ed. Università di Perugia, Perugia, Italy.
- BERTRAM, H. C., WHITTAKER, A. K., SHORTHORSE, W. R., ANDERSEN, H. J., KARLSSON, A. H., 2004. Water characteristics in cooked beef as influenced by ageing and high-pressure treatment – an NMR micro imaging study. *Meat Sci.* 66:301-306.
- BOAKYE, K., MITTAL, G. S., 1993. Changes in pH and water holding properties of *longissimus dorsi* muscle during beef ageing. *Meat Sci.* 34:335-349.
- BOAKYE, K., MITTAL, G. S., 1996. Changes in colour of beef *M. longissimus dorsi* muscle during ageing. *Meat Sci.* 42:347-354.
- CAMPO, M. M., SAÑUDO, C., PANEA, B., ALBERTI, P., SANTOLARIA, P., 1999. Breed type and ageing time effects on sensory characteristics of beef strip loin steaks. *Meat Sci.* 51:383-390.
- DRANSFIELD, E., 1996. The texture of meat: condition-

- ing and ageing. In S. A. Taylor, A. Raimundo, M. Severini, F. J. M. Smulders (Eds.) Meat quality and meat packaging. Ed. University of Utrecht, The Netherlands, pp 65-87.
- ECC, 1981a. Commission Regulation N. 2930/81 of October 12, 1981, adopting additional provisions for the application of the Community scale for the classification of carcasses of adult bovine animals. Official Journal, L 293 (13/10/1981), 6-7.
- ECC, 1981b. Council Regulation N. 1208/81 of April 28, 1981, determining the Community scale for the classification of carcasses of adult bovine animals. Official Journal, L 123 (07/05/1981), 3-6.
- ECC, 1991. Council Regulation N. 1026/91 of April 22, 1991, amending Regulation (EEC) N. 1208/81 determining the Community scale for the classification of carcasses of adult bovine animals. Official Journal, L 106 (26/04/1991), 2-3.
- GAŠPERLIN, L., ŽLENDER, B., ABRAM, V., 2001. Colour of beef heated to different temperatures as related to meat ageing. *Meat Sci.* 59:23-30.
- GEESINK, G. H., KOOLMEES, P. A., VAN LAACK, H. L. J. M., SMULDERS, F. J. M., 1995. Determinants of tenderisation in beef *Longissimus dorsi* and *Triceps brachii* muscles. *Meat Sci.* 41:7-17.
- HWANG, I. H., THOMPSON, J. M., 2001. The interaction between pH and temperature decline early post-mortem on the calpain system and objective tenderness in electrically stimulated beef *longissimus dorsi* muscle. *Meat Sci.* 58:167-174.
- JUNG, S., GHOUL, M., DE LAMBALLERIE-ANTON, M., 2000. Changes in lysosomal enzyme activities and shear values of high pressure treated meat during ageing. *Meat Sci.* 56: 239-246.
- KOOHMARAIE, M., 1996. Biochemical factors regulating the toughening and tenderization processes of meat. *Meat Sci.* 43:S193-S201.
- KOOHMARAIE, M., KENT, M. P., SHACKELFORD, S. D., VEISETH, E., WHEELER, T. L., 2002. Meat tenderness and muscle growth: is there any relationship? *Meat Sci.* 62:345-352.
- MACLEOD, G., 1998. The flavour of beef. In F. Shahidi (Ed.) Flavor of meat and meat products and seafoods. 2nd ed. Blackie Academic & Professional, London, UK, pp 27-60.
- MEILGAARD, M., CIVILLE, G. V., CARR, B. T., 1991. Sensory evaluation techniques. 2nd ed. CRC Press Inc., Boca Raton, Florida, USA.
- MILLER, M. F., KERTH, C. R., WISE, J. W., LANSDALL, J. L., STOWELL, J. E., RAMSEY, C. B., 1997. Slaughter plant location, USDA quality grade, external fat thickness, and aging time effects on sensory characteristics of beef loin strip steak. *J. Anim. Sci.* 75:662-667.
- PALKA, K., 2003. The influence of post-mortem ageing and roasting on the microstructure, texture and collagen solubility of bovine semitendinosus muscle. *Meat Sci.* 64:191-198.
- PIASENTIER, E., VALUSSO, R., VOLPELLI, L. A., FAILLA, S., 2003. Meat quality of Italian Simmental young bulls as affected by the genes frequency of Montbéliarde origin. pp. 187-188 in Proc. 49th Int. Congr. of Meat Science and Technology. R. Vieira Grafica - Editoria Ltda, Campinas, São Paulo, Brasil.
- PURCHAS, R. W., YAN, X., HARTLEY, D. G., 1999. The influence of a period of ageing on the relationship between ultimate pH and shear values of beef m. *longissimus thoracis*. *Meat Sci.* 51:135-141.
- SHERBECK, J. A., TATUM, J. D., FIELD, T. G., MORGAN, J. B., SMITH, G. C., 1995. Feedlot performance, carcass traits, and palatability traits of Hereford and Hereford x Brahman steers. *J. Anim. Sci.* 73:3613-3620.
- SILVA, J. A., PATARATA, L., MARTINS, C., 1999. Influence of ultimate pH on bovine meat tenderness during ageing. *Meat Sci.* 52:453-459.
- THOMPSON, J., 2002. Managing meat tenderness. *Meat Sci.* 62:295-308.
- WHEELER, T. L., KOOHMARAIE, M., 1994. Prerigor and postrigor changes in tenderness of ovine longissimus muscle. *J. Anim. Sci.* 72:1232-1238.
- ZAMORA, F., DEBITON, E., LEPETIT, J., LEBERT, A., DRANSFIELD, E., OUALI, A., 1996. Predicting variability of ageing and toughness in beef *longissimus lumborum et thoracis*. *Meat Sci.* 43: 321-333.