Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (INIA)
Available online at www.inia.es/sjar

Spanish Journal of Agricultural Research 2008 6(1), 25-32
ISSN: 1695-971-X

Effect of ageing method, ageing period, cooking method and sample thickness on beef textural characteristics

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Abstract

The effect of the ageing method (bone-in or boneless), ageing period (7 or 14 days), cooking method (grilling or water bath preparation) and sample thickness (1, 2 or 4 cm) on the meat texture characteristics of the *longissimus thoracis* muscle of six young, commercial bulls was measured using a texture analyser incorporating compression and Warner-Bratzler devices. The sarcomere length of the raw meat and cooking losses were also recorded. The ageing method and ageing period had more influence on the textural properties studied than either the cooking method or sample thickness. Cooking losses were, however, mainly influenced by the cooking method. Although the cooking method had no significant effect on meat toughness, the meat tended to be tougher when grilled than when prepared in a water bath. Meat tenderness mainly improved during the first week of storage.

Additional key words: compression, instrumental analysis, meat quality, Warner-Bratzler test.

Resumen

Efecto del método de maduración, tiempo de maduración, método de cocinado y espesor de la muestra sobre algunas características texturales de la carne de vacuno

Se ha estudiado el efecto del método de maduración (con o sin hueso), el tiempo de maduración (7 ó 14 días), el método de cocinado (grill o baño de agua) y el espesor de la muestra (1, 2 ó 4 cm) sobre la textura del *longissimus thoracis* de 6 añojos de tipo comercial. El ensayo se llevó a cabo utilizando dos células distintas (compresión y Warner-Bratzler). Asimismo se midieron la longitud de los sarcómeros de la carne cruda y las pérdidas por cocinado. El método y el tiempo de maduración fueron más importantes que el método de cocinado o el espesor de la muestra en las características de textura. El método de cocinado afectó principalmente a las pérdidas por cocinado. Aunque el método de cocinado no afectó significativamente a la dureza, la carne tendió a ser más dura al grill que un baño de agua. La dureza de la carne disminuyó con la maduración, especialmente en la primera semana.

Palabras clave adicionales: análisis instrumental, calidad de la carne, compresión, Warner-Bratzler.

Introduction[1]

The quality of raw and cooked meat can be studied using a number of instrumental or sensorial methods. One of the most important concerns in such studies (besides the high cost) is the standardisation of the analysis conditions, including the ageing method, the ageing period, the sample thickness, the initial cooking temperature, the real cooking temperature, and the time of cooking.

It is well known that different cooking techniques, durations of cooking and core temperatures have a great effect on the physical properties of meat and its eating quality (Combes *et al.*, 2003). The cooking technique affects three main variables: the temperature of the meat surface, the temperature profile throughout

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Received: 11-05-07; Accepted: 19-11-07.

[1] Abbreviations used: AM (ageing method), AP (ageing period), CM (cooking method), EU (European Union), N (maximum load), ST (steak thickness), WB (Warner-Bratzler).

the meat, and the method of heat transfer (e.g., via contact or via air or steam). The temperature gradient in the meat influences the rate and extent of protein structure change, whereas the method of heat transfer influences the sensorial perception of the cooked product (Bejerholm and Aaslyng, 2003). The changes observed in meat tenderness during cooking result from modifications occurring in the connective tissue and myofibril proteins. Heat solubilizes collagen, which implies the tenderisation of the meat, but it also denatures the myofibrilar proteins, thus increasing its toughness; the net effect depends on the cooking conditions (Obuz *et al.,* 2003).

When measured by instrumental methods, meat toughness is seen to increase over two stages, the first between 40 and 50°C, and the second between 60 and 80°C. A reduction in meat toughness occurs, however, at temperatures of 50-60°C. The first peak in toughness is due to the denaturation of myosin, the following reduction in meat toughness between 50 and 60°C is caused by a reduction in the breaking strength of the connective tissue (due to partial denaturation of the collagen fibres), and the second increase in toughness is a consequence of the denaturation of the other myofibrilar proteins (Christensen *et al.,* 2000). These major changes occur at the temperatures often used in instrumental meat quality analyses, and even in sensorial analyses.

It is well known that ageing has a decisive effect on the quality of the product (Dransfield, 1994; Koohmaraie, 1996; Sañudo *et al.,* 2004). In the majority of studies, samples have been taken as early as possible —yet under commercial conditions meat can remain on the carcass for several days until being sold. The question therefore arises as to whether ageing proceeds in the same fashion when meat remains on the carcass and when it is separated from it and sliced. Some authors have indicated that sarcomere length also helps determine meat texture (Palka and Daun, 1999), although results in this area have often been contradictory. The effect of sarcomere length is, therefore, far from being understood.

The above factors also affect cooking losses. Cooking losses are of interest since they may explain part of the variation in juiciness between different meat samples, and because they influence meat appearance (Aaslyng *et al.,* 2003). Although some authors have shown that sample preparation decisively influences the results of experiments (Lewis and Purslow, 1990), in studies examining the factors that affect meat texture, sample thickness is rarely taken into account.

The aim of the present study was to determine how the ageing method, ageing period, cooking method and sample thickness affect a number of beef instrumental textural variables. The study of these factors may help in the optimisation of meat quality.

Material and Methods

Sampling

The experimental meat was 12 striploins taken from six young, commercial bulls (entire males). All animals were stunning by a captive bolt pistol and slaughtered at a commercial EU licensed abattoir. The carcasses were dressed according to normal commercial practice in Spain, and chilled at 4°C ± 1°C for 24 h. A portion of every striploin (right and left sides) from between the 5^{th} and 13^{th} thoracic ribs was then excised, including the bone, and transported to the laboratory.

The different samples were processed according to two ageing methods, two ageing periods, two cooking methods, and three steak thicknesses. The left halves of the carcasses were aged bon-in, and the right halves aged boneless. Two periods (7 and 14 days) were used to study the effect of ageing. Two cooking methods, grilling and water bath preparation, were chosen to study the effect of cooking procedure. The samples were chopped into 1, 2 or 4 cm-thick steaks; the thickness of steaks is a reliable marker of their required cooking time, and therefore of the possible behaviour of the water inside the meat during heating.

As controls, a number of samples (termed «initial samples») were taken at 24 h from the cranial edge of the loins, sliced into 1 cm, 2 cm or 4 cm-thick steaks, and subjected without ageing to the same cooking treatments as the experimental samples. The overall design is shown in Figure 1; the characteristics of the initial samples are shown in Table 1.

Analysis

Sarcomere length was measured using a portion of the 4 cm raw steaks, following the method described by Torrescano *et al.* (2003).

For texture analysis, the steaks were thawed in tap water for 4 h until reaching an internal temperature of about 15°C. Samples with a cross sectional area of 1 cm^2 were cut using longitudinal configuration (Lepetit and

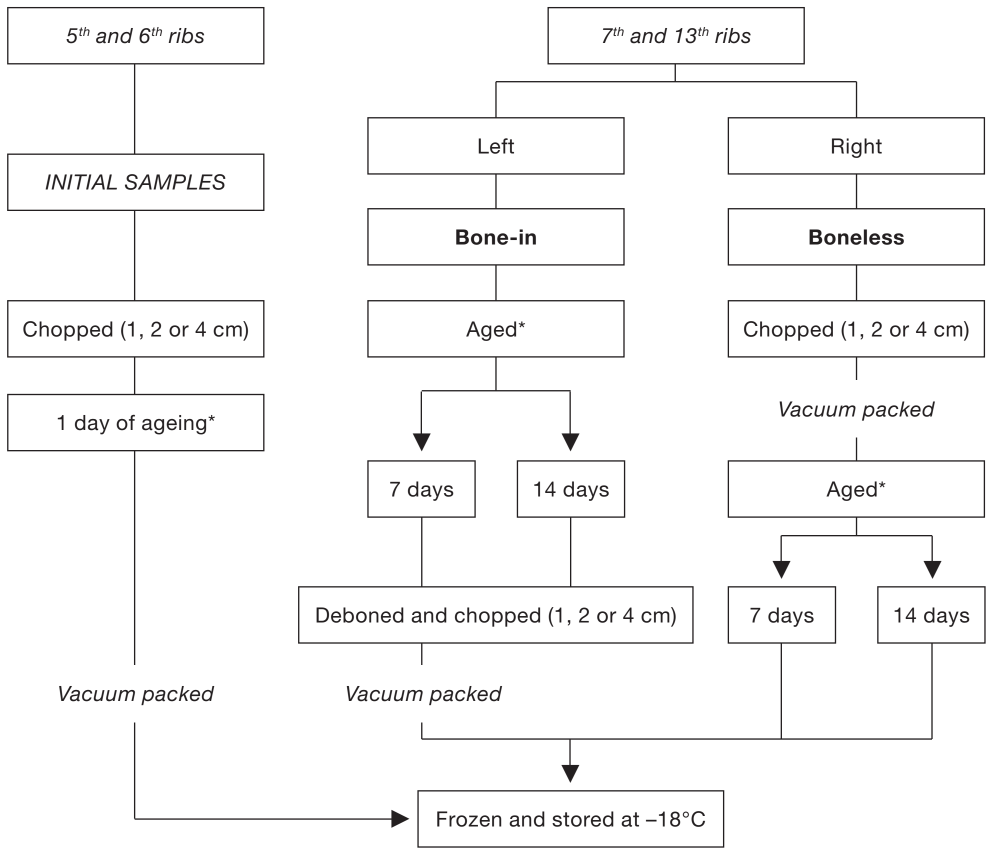

Figure 1. Treatment of the experimental meat (longissimus thoracis muscle). * In all cases ageing proceeded at 4°C.

Table 1. Mean and standard deviation of the studied variables in the «initial samples»

Variable	Cooking method[1]	Sample thickness (cm)	Mean	SD
Sarcomere length (µm)	Raw	4	2.03	0.18
Compression load (N)	Raw	4	51.53	7.53
Stress at 20% of the max. comp. (N cm^{-2})	Raw	4	13.14	3.20
Stress at 80% of the max. comp. (N cm^{-2})	Raw	4	40.25	6.51
Maximum WB load (N)	Water bath	1	58.42	17.20
		2	73.08	14.81
		4	67.27	14.18
	Grill	1	76.42	8.30
		2	74.90	18.18
		4	98.83	13.41
Cooking losses (%)	Water bath	1	18.87	5.89
		2	19.19	1.81
		4	20.68	4.46
	Grill	1	28.42	3.26
		2	28.54	3.13
		4	31.35	1.82

[1] Sarcomere length was measured in raw meat. The compression test was performed on raw meat following the method of Lepetit and Culioli (1994). Warner-Bratzler tests were carried out on cooked meat.

Culioli, 1994) and analysed using an Instron 4301 texture analyser. Raw meat was analysed using a modified compression device that avoids transversal elongation of the sample (Lepetit and Culioli, 1994). The load at maximum compression (N) and the stress at 20% and 80% of the maximum compression ($N*cm^{-2}$) were recorded. For the Warner-Bratzler (WB) test, samples was cooked in a water bath at 80°C or on a pre-heated double plate griddle at 200°C, in both cases until the internal temperature reached 70°C. Internal temperature was monitored using a Jenway probe. The load maximum (N) was then recorded. Cooking losses (expressed as a percentage) were estimated as the weight-difference between the thawed and cooked steak (Pla, 2000).

Statistical analysis was performed using SPSS 12.0 software; the GLM procedure was used to determine the significance of the fixed effects taken into account.

The statistical model used for raw meat (sarcomere length and compression test) was:

$$\mu + AM_i + AP_j + AM_i{*}AP + \varepsilon_{ij}$$

where AM = ageing method, AP = ageing period, i = 1 (boneless) or 2 (bone-in) and j = 7 or 14 days of ageing.

The statistical model used for cooked meat (Warner-Bratzler test and cooking losses) was:

$$\mu + AM_i + AP_j + CM_k + ST_l + AM_i{*}AP_j + AM_i{*}CM_k + + AM_i{*}\ ST_l + AP_j{*}CM_k + AP_j{*}ST_l + CM_k{}^{*}ST_l + e_{ijkl}$$

where CM = cooking method, ST = steak thickness, i = 1 (boneless) or 2 (bone-in), j = 7 or 14 days of ageing, k = 1 (water bath preparation) or 2 (grilling), and l = 1, 2 or 4 [sample thickness (cm)].

When an effect was significant, ANOVA was performed to analyse this effect nested within the others. Differences between means were calculated using the Duncan test.

Finally, to illustrate the importance of the heating rate on cooking losses, the time taken to reach the final internal temperature at the core of the steak was recorded every minute in a number of samples.

Results

Table 2 shows the significance of the effects of the different processes studied on the meat texture variables. Neither the ageing method nor the ageing period influenced sarcomere length. Consequently, under the present conditions, it may be assumed that sarcomere length had no affect on the texture results. In the compression test, the ageing method affected the maximum compression load and the stress recorded at 80% of maximum compression, but not at 20%. In contrast, the ageing period affected the stress recorded at 20% of the maximum compression, but not at 80% or at maximum compression. No interactions were observed between the compression variables. The maximum load in the WB test was mainly affected by the ageing method and the ageing period, and somewhat less by the sample thickness. Cooking losses were affected neither by the method nor the ageing period, but were slightly affected by sample thickness; the determining factor was the cooking method. With respect to cooking losses, the

Table 2. Effect of ageing method (bone-in or boneless), ageing period (7 or 14 days), cooking method (water bath preparation or grilling and sample thickness (1, 2 or 4 cm) on the studied variables. All figures are P values. The GLM procedure was performed independently for cooked and raw meat

	Raw meat				Cooked meat	
	Sarcomere length (µm)	Compression load (N)	Stress at 20% ($N\ cm^{-2}$)	Stress at 80% ($N\ cm^{-2}$)	Maximum load WB (N)	Cooking losses (%)
Ageing method (AM)	0.31	0.01	0.49	0.01	0.00	0.29
Ageing period (AP)	0.14	0.58	0.00	0.31	0.00	0.75
Cooking method (CM)					0.42	0.00
Sample thickness (ST)					0.04	0.05
AM×AP	0.06	0.50	0.94	0.73	0.66	0.23
AM×CM					0.21	0.39
AM×ST					0.45	0.55
AP×CM					0.21	0.76
AP×ST					0.91	0.52
CM×ST					0.57	0.05

Table 3. Means and standard deviation for sarcomere lenght and compression test variables

Ageing method	Ageing period (days)	Sarcomere length (µm)	Compression load (N)	Stress at 20% max. comp. (N cm^{-2})	Stress at 80% max. comp. (N cm^{-2})
Bone-in	7	2.22 (0.25)	62.14 (12.40)	4.77 y (0.41)	44.36 b (9.97)
	14	1.99 (0.07)	60.58 b (13.07)	3.60 x (0.30)	44.29 b (9.93)
Boneless	7	2.02 (0.07)	55.04 (10.37)	4.51 y (0.82)	33.20 a (1.44)
	14	2.05 (0.16)	44.98 a (5.52)	3.40 x (0.38)	30.88 a (3.88)

[a,b] Different letters in the same column reflect significant differences between the ageing methods ($p < 0.05$). [x,y] Different letters in the same column reflect significant differences between the ageing periods ($p < 0.05$).

interaction *cooking method × sample thickness* showed a trend towards significance ($p = 0.054$).

Table 3 shows the means and standard deviations for the sarcomere length and compression test variables. The effect of the ageing method on the compression load was noticeable only after 14 days. Nevertheless, the effect of the ageing method on stress at 80% of the maximum compression was significant after both 7 and 14 days. In all cases, values were higher in the bone-in method. This suggests that attachment to the bone increases the resistance offered by the connective tissue. Independent of the ageing method, the stress at 20% of the compression decreased with increasing ageing period. Table 4 shows the effect of the ageing method and ageing period on WB load. Unlike in the compression test, the WB load values were higher for the boneless ageing method. This reflects the effect of cooking on the physical interaction between the myofibrils and connective tissue. The WB load values were higher at 7 days of ageing than at 14 days, as expected.

Figure 2 shows the effect of the cooking method on cooking losses. The latter were greater for grilling than for water bath preparation, independent of the ageing method, ageing period or sample thickness.

Table 4. Effect of ageing method and ageing period on maximum WB load

Ageing method	Ageing period (days)	Maximum WB load (N)
Bone-in	7	48.60 ax (13.35)
	14	37.30 ay (8.72)
Boneless	7	59.73 bx (13.42)
	14	50.78 by (11.11)

[a,b] Different letters in the same column reflect significant differences between the ageing methods ($p < 0.05$). [x,y] Different letters in the same column reflect significant differences between the ageing periods ($p < 0.05$).

Figure 3 shows the heating rates recorded; the raw data fitted logarithmic curves. The square point line corresponds to the temperatures recorded every minute at the core of a 1 cm-thick steak, the diamond point line corresponds to a 2 cm thick steak, and the circle point line corresponds to a 4 cm-thick steak. The slope of the curves becomes lower as thickness increases. For example, a 1 cm-thick steak would need about 6 min on average to reach 70°C, but a 2 cm thick steak would need about 18 min, and a 4 cm-thick steak about 37 min. The cooking rates are 11.7°C min^{-1} for a 1 cm steak, 3.9°C min^{-1} for a 2 cm steak, and 1.9°C min^{-1} for a 4 cm steak. Since the increase is not linear, a 2 cm-thick steak would reach around 52°C after 6 min, whereas a 4 cm steak would only reach a temperature of about 39°C; at 18 min, a 4 cm thick steak would reach around 60°C.

Discussion

The present results regarding the effect of sarcomere length agree with those of Culler *et al.* (1978), Seideman *et al.* (1987) and Rao *et al.* (1989). Those for the texture variables and their variability agree with those reported by several authors (Campo *et al.*, 2000; Renand *et al.,* 2001; Monsón *et al.,* 2004; Sañudo *et al.*, 2004).

The literature contains little information on the ageing of meat on the carcass, and where it does exist the effect of ageing was not the aim of the study; rather, the focus was on the effects of electrical stimulation, the carcass suspension method, and very fast chilling (Taylor and Cornell, 1986; Fapohunda and Okubanjo, 1987; Sørheim *et al.,* 2001). This makes the comparison of results very difficult. In the present work, the ageing method induced no significant differences in sarcomere length, although the fact that stress at 80% of the maximum compression was higher in the bone-in-aged meat suggests that a slight stretching of the muscle occurs, and that the tension

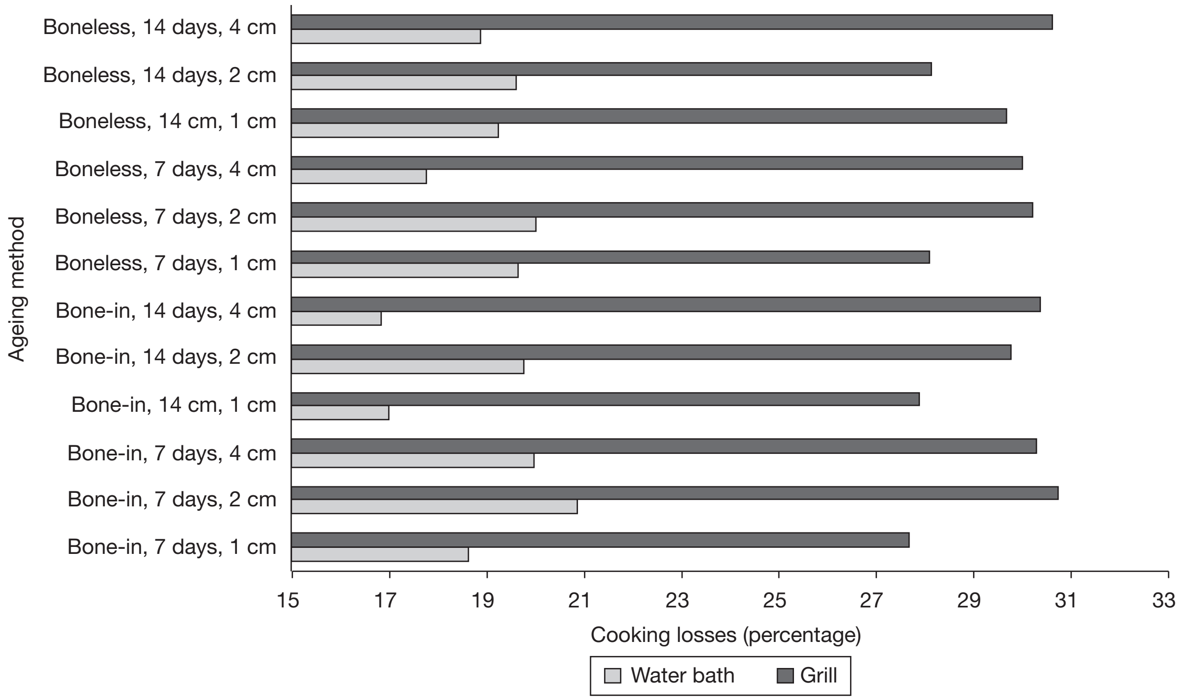

Figure 2. Effect of ageing method on cooking losses.

that the bone exerts on the muscle can alter some of its characteristics. As reported by Rowe (1977), the angle between the connective tissue and the myofibrils changes if the fibres are stretched or shortened, and meat toughness could be linked to these changes: if a fibre is stretched, this angle becomes higher than the natural value of (approximately) 55°, which causes the connective tissue to exert resistance to compression earlier than in a normal or in a contracted muscle. When meat is cooked, however, the connective tissue is denatured and it can exert no more resistance. Palka (1999) reported that about 50% of collagen to be solubilized at around 70°C, and that sarcolemma denaturation is underway. Hence, if this slight stretching really occurs, cooked meat should be slightly less tough; this was confirmed by the present results. This is in agreement with the conclusions of Bouton *et al.* (1981). These authors compared the shear force of raw muscle when

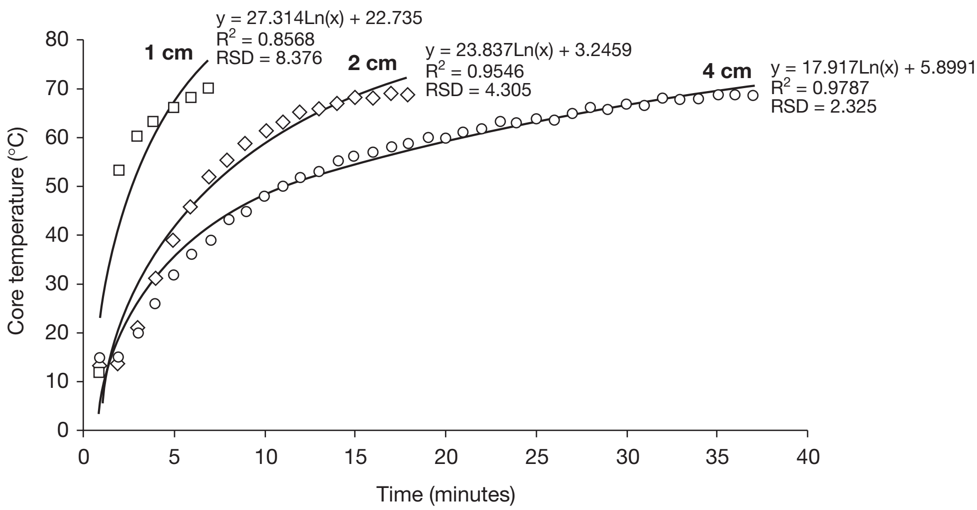

Figure 3. Heat transfer in samples of different thickness (water bath at 80°C); the data fit logarithmic curves.

stretched or cold-shortened, and concluded it to be higher in stretched muscles. In cooked meat, however, the opposite was true, the inflexion point being around 58°C.

The effect of the ageing period on the texture characteristics of the meat was clearer. This has been widely studied (Lewis *et al.,* 1991; Dransfield, 1994; Campo *et al.*, 2000; Sañudo *et al.*, 2004). The effect of ageing on stress at 20% of the maximum compression was more important in the first week than in the second. The differences in stress at the 20% value between day 1 and day 7 of ageing were 8.37-8.87 N cm^{-2}, whereas the differences between day 7 and day 14 was only 0.87-1.17 N cm^{-2}. This means that the stress at 20% compression fell about 65% in the first week but only about 11% in the second one. We have reported similar results in previous work (Sañudo *et al.,* 2004), as have other authors. For example, in a study involving heifers, White *et al.* (2004) reported that most tenderisation occurred before the third day of ageing.

With respect to cooking losses, the present water bath results agree with those of Fiems *et al.* (2003), and the grill results are similar to those of Panea (2002). The cooking method had the most important effect on cooking losses. Cooking losses are affected by three main variables: the surface temperature of the meat, the heat transfer method, and the internal temperature profile (i.e., temperature/time). The surface temperature of the grilled steaks was clearly higher than that achieved by the water bath method. Further, the transfer of heat was slower in this second method; heat was exchanged with released meat juice, whereas in the grill method heat exchange occurred with the air. Steaks therefore need more time to cook in a water bath than on a grill; the heating rate is higher with the grill method, and heating rate is a crucial factor in cooking losses (Aaslyng *et al.*, 2003; Obuz *et al.,* 2003).

Figure 3 shows the heating ratio became ever slower as thickness increased. Thus, heat transfer follows a complex model inside steak, and is affected by the cooking method, cooking time, and cooking temperature, but also by the shape of the sample. Standardised experimental conditions would therefore be a boon in texture studies.

In summary, the ageing method and ageing period are important in determining the texture characteristics of meat, whereas the cooking method has the greatest influence on cooking losses. In general, grilled meat should be less tender than meat cooked in a water bath.

Although ageing improves the tenderness of meat, storage can have important economic consequences. Since most tenderisation take place in the first week of storage, longer ageing periods should not be recommended for the meat of young animals.

Acknowledgments

The authors thank Pere Albertí and María del Mar Campo for critical reading of the manuscript, Juan José Pardos for technical assistance, and Bimarca S.A. for its collaboration in this work.

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