Meat tenderness: aging management of nine beef muscles

Marzin V. [1], Tribot-Laspière P.[1], Turin F.[1], and Denoyelle C.[2]

[1] Livestock Institute (IDELE, Institut de l'Elevage), Meat quality, Villers Bocage, France
[2] Livestock Institute (IDELE, Institut de l'Elevage), Meat quality, Paris, France

Abstract - **This study was conducted to characterize improvements in tenderness with postmortem aging of 4 individual beef muscles from 2 animal types and to validate the optimal aging time of 9 muscles to better satisfy French consumers. Moreover, the effect of long periods of aging on meat tenderness is also studied. The aim is to provide industry with guidance for management of aging. Tenderness improvements were evaluated over 4 periods of aging (3, 7, 14 and 21 days) via sensory analysis with an expert panel. The level of tenderness acceptability was then determined for the 9 muscles at each aging time by a consumer panel. The tenderness improvement by using long aging periods was evaluated up to 90 days on the *LD*. Although the overall change in tenderness of a given muscle is not influenced by the animal type, the gains of tenderness are not always obtained during the same aging period in dairy cows and young bulls. Consumer acceptability of tenderness for each muscle at each aging time is coherent with the aging patterns determined by the experts. It enables professionals to adapt aging to their objectives in terms of consumer satisfaction. Tenderness of LD significantly improves up to 60 days aging. However, aging up to 90 days does not real add value in terms of tenderness since bad tastes begin to appear. The results provide data to industrials that allow managing beef aging while taking into account the percentage consumer satisfaction they target.**

Keywords— **aging, beef, tenderness**

I. INTRODUCTION

Meat tenderness is a primary criterion of beef quality [1]. Postmortem aging is a critical management practice that can improve the consistency of beef tenderness [2]. However, the recent French National Beef Tenderness Survey revealed variability in length of postmortem aging time of beef cuts and poor or infrequent aging management by the French industry [3]. Previous studies have characterized improvements in tenderness associated with a variety of beef muscles [4,5]. Nevertheless, data is lacking as to how this improvement is perceived by French consumers and as to the level of tenderness that they judge to be acceptable [6]. As a large share of meat market trade involves whole muscles, vacuum packaged, and consumer sales units, it is in the interest of professionals to optimize muscle aging, in accordance with their commercial destination, their aging pattern, logistical constraints and customer satisfaction objectives. This study consisted of characterizing the aging profile of 4 beef muscles, then determining the level of acceptability with regards to tenderness, in accordance with the aging period for all 9 muscles. The effects of long aging periods were also measured on one muscle. The objective was to provide the professionals with elements for managing "à la carte" aging.

II. MATERIALS AND METHODS

A. The aging pattern of 4 muscles

Twenty-four young bull (YB) carcasses (17 months ±1) and 24 dairy cow (DC) carcasses (69 months ± 28) were used. On each carcass, *adductor femoris* (AF), *biceps femoris* (BF), *gluteus medius* (GM), *vastus lateralis* (VL) were removed and appropriately prepared according to the procedures described by Denoyelle et al. [7]. Each muscle was cut into 12 portions which were then randomly distributed into 4 bags and vacuum packaged. The sample bags were stored for 3, 7, 14 or 21 days at 1-2°C, then frozen at -18°C. The day prior to the sensory analysis, the samples were defrosted 24 hrs at +4°C. For sensory analysis, the samples were cooked in muffle furnaces until they reached a central temperature of 57°C. Sixty-four sessions of sensory analysis were carried

out, with a panel of 12 experts. During a session, the same taster would compare the 4 aging durations of the same muscle from the same animal, according to a balanced comparative system of 3 out of 4. Expert panelists were asked to evaluate samples using 100-point scales for level of tenderness (0=extremely tough; 100=extremely tender).

B. Consumer acceptability of tenderness

20 dairy cow carcasses (65 months ± 25) were used. For each carcass, 9 muscles were removed: *adductor femoris (AF), biceps femoris (BF), gluteus medius (GM), vastus lateralis (VL), longissimus dorsi (LD), semi membranosus (SM), rectus femoris (RF), semi tendinosus (ST), triceps brachii (TB)*. Each muscle was cut into 4 steaks, then randomly distributed into 4 bags, vacuum packed. The sample bags were conserved for 3, 7, 14 or 21 days at 1-2°C, then frozen at -18°C before sensory analysis. The day prior to the tasting session, the samples were defrosted over 24 hours at +4°C. For tasting, the samples were cooked using a professional electric grill until reaching a central temperature of 57°C. Eighteen sensory analysis sessions were carried out, with a panel of 360 consumers. During one session, each consumer received 8 samples, in accordance with a sequential monadic testing procedure. They were asked to specify whether the level of tenderness was, in their opinion, acceptable or not.

C. Long duration aging

24 *Longissimus dorsi* were removed from 24 dairy cow carcasses (75 ± 21 months). Each muscle was cut into 4 slices of 1 kg and randomly distributed into 4 bags, then vacuum packed. The samples were stored for 3, 21, 60 and 90 days at -1.5°C, then frozen before sensory analysis. The day prior to the tasting session, the samples were defrosted over 24 hours at +4°C. Eight sensory analysis sessions were carried out, with a panel of 12 experts per session. During a session, the same expert would compare the 4 aging durations of the same muscle from the same animal, according to a balanced comparative system of 3 out of 4. Expert panelists were asked to evaluate samples using 100-point scales for the level of tenderness (0=extremely tough; 100=extremely tender), and flavour (0=absent flavour; 100=very pronounced flavour).

D. Statistical analysis

The mixed procedure of SAS was used to run the statistical analysis of variance. The means were compared by Tukey Kramer test.

III. RESULTS AND DISCUSSION

A. The aging pattern of 4 muscles

There was no significant difference between the tenderness of the dairy cows' meat (DC) and that of the young bulls' meat (YB). On the other hand, the existence of a significant interaction between the type of animal and the aging duration ($p<0.005$) indicates that with regards to the type of animal, the aging effect is not identical. Indeed, depending on the type of animal tenderness gains are not obtained at the same time during the aging process. The average scores awarded by the panel of experts for the various aging durations are shown in Table 1.

Table 1 : Mean tenderness scores by muscle, aging time and animal type

Muscle	Animal type	Postmortem aging (days)			
		3 d.	7 d.	14 d.	21 d.
Adductor femoris	YB	44,6^{a}	48,0^{a}	55,9^{b}	57,8^{b}
	DC	41,5^{a}	46^{a}	53,5^{b}	59,2^{c}
Biceps femoris	YB	54,9^{a}	54,3^{a}	63,0^{b}	64,7^{b}
	DC	52,2^{a}	57,6^{b}	59,6^{b}	62,2^{b}
Gluteus medius	YB	48,5^{a}	51,4^{a}	58,2^{b}	62,9^{b}
	DC	45,5^{a}	51,4^{b}	54,6^{b}	60,2^{c}
Vastus lateralis	YB	36,8^{a}	40,1^{a}	45,6^{b}	49,5^{b}
	DC	31,9^{a}	37,3^{b}	39,3^{b}	46,4^{c}

^{a,b,c,d} : means with same superscript on same row are not significantly different at $p<0,05$

In the YB, the 4 muscles present similar aging pattern: there was no significant difference in tenderness between 3 and 7 days of aging but the period comprising between 7 and 14 days of aging consistently shows a significant gain in tenderness. This period significantly contributes to the aging

response of the YB muscles (e.g. the overall tenderness improvement that occurs during aging from day 3 through day 21): corresponding to 61% ($p<0.001$) of the *AF* aging response, 83% ($p<0.001$) of that for *BF*, 47% of that for *GM* ($p<0.01$) and 43% of that for *VL* ($p<0.05$) (Table 2). In the period comprising between 14 and 21 days, the increase in tenderness is weak and not significant for the 4 muscles.

Table 2 : Part of the aging response obtained by muscle and by animal type in each period of aging.

Animal	Muscle	Aging response	Aging period (days)		
			3-7	7-14	14-21
Dairy Cows	Adductor femoris	17,7 pts	26%	42%	32%
	Biceps femoris	10 pts	54%	20%	26%
	Gluteus medius	14,7 pts	40%	22%	38%
	Vastus lateralis	14,5 pts	37%	14%	49%
Young bulls	Adductor femoris	13 pts	25%	61%	13%
	Biceps femoris	9,8 pts	0%	83%	17%
	Gluteus medius	14,4 pts	20%	47%	33%
	Vastus lateralis	12,7 pts	26%	43%	31%

While the tenderness gain in the young bull was mainly obtained between 7 and 14 days for all muscles, the kinetics differed in the dairy cow muscles. For *VL* and *GM*, the significant differences in tenderness were demonstrated between 3 and 7 days, then between 7 and 21 days, with the period comprising of between 7 and 14 days bearing no significant tenderness gain. For *BF*, the increase in tenderness is only significant between 3 and 7 days of aging. The aging kinetics of *AF* is similar to that of the YB up to 14 days, but the increase in tenderness continues, however, in a significant manner between 14 and 21 days (+5.7 pts; $p<0.05$). Based on their aging response, *AF*, *VL* and *GM* showed strong potential improvement in their tenderness: aging for 21 days enabled a tenderness gain of between 30 and 40% in relation to the initial level of tenderness. On the other hand, *BF* had a low potential for improvement (18% in relation to the initial level of tenderness). This data was, however, to be linked with its high initial level of tenderness.

B. Tenderness acceptability based on the aging duration

The percentages of consumers judging the acceptable meat tenderness according to the aging duration are shown in Table 2. After 3 days of aging, the tenderness of the majority of the muscles was acceptable for only 50 to 60% of consumers. After 7 days of aging, two thirds of consumers judged the tenderness to be acceptable. This percentage was 70 to 80% after 14 days. For most of the muscles, a 21-day aging period was able to satisfy 80% of consumers.

Table 3: percentage of consumers judging acceptable the meat tenderness by aging duration and muscle

Muscle	Postmortem aging			
	3d.	7d.	14d.	21d.
Adductor femoris (ADD)	$63,6^{a}$	$66,3^{a}$	$79,2^{ab}$	$86,6^{b}$
Biceps femoris (AR)	$60,6^{a}$	$68,4^{ab}$	$78,6^{ab}$	$83,6^{b}$
Gluteus medius(RUM)	$44,4^{a}$	$70,5^{b}$	$80,9^{b}$	$84,6^{b}$
Longissimus dorsi (FF)	$55,4^{a}$	$71,4^{ab}$	$70,1^{a}$	$87,6^{b}$
Rectus femoris(RTG)	$62,2^{a}$	$66,3^{ab}$	$70,4^{ab}$	$82,1^{b}$
semi membranosus	$55,4^{a}$	$58,2^{a}$	$67,6^{ab}$	$81,7^{b}$
semi tendinosus (RG)	$55,3^{a}$	$67,4^{ab}$	$77,8^{b}$	$72,6^{ab}$
Triceps brachii (MAC)	$69,1^{a}$	$59,7^{a}$	$73,1^{a}$	$71,8^{a}$
Vastus lateralis(PTG)	$51,2^{a}$	$49,7^{a}$	$59,8^{a}$	$68,3^{a}$

^{a,b} : values with same superscript on same row are not significantly different at $p<0,05$

C. Long aging duration

The aging curve of the LD was characterized by a rapid increase phase in tenderness up to 21 days, followed by a modest increase phase up to 60 days. Finally, between 60 and 90 days, even though aging did not significantly improve tenderness (plateau phase), a tendency towards improvement seemed to emerge ($p=0.07$) (Table 4). The overall satisfaction scores for the 90-day samples, significantly higher ($p<0.05$) than those of the 60-day samples, confirmed this tendency, causing the assumption that tenderness continues to increase, even if it is extremely slowly.

Table 4 : Mean tenderness scores and part of the aging response completed by aging time

	Postmortem aging (days)			
	3	21	60	90
Mean Tenderness scores	38,0 ± 11,6[a]	55,2 ± 10,9[b]	65,8 ± 9,2[c]	69,6 ± 8,1[c]
Percentage of the aging response completed	54,6%	79,3%	94,5%	100%

[a,b,c,d] : means with same superscript on same row are not significantly different at p<0,05

After 3 days of aging, *LD* only reached slightly higher than half of its aging response (90-day tenderness level), it reached 80% of this potential at 21 days and 94.5% at 60 days of aging. The analysis of the flavour scores showed that there was no significant difference between the cuts aged for 21 days and those aged for 60 days, nor between those aged for 60 days and those aged for 90 days. However, out of all the samples tasted (N=1152), 16 were reported by the tasters as having a "bad taste" (1.38%). These flavour defects concerned 11 samples aged for 90 days, 4 samples aged for 60 days and 1 sample aged for 21 days. One particular animal had 9 cases of "bad taste" alone out of the 16 cases reported, and this began at 21 days of aging. However, the presence of this bad taste in the samples aged for 90 days concerned 7 different animals out of the 24 tested. The fat colour was slightly altered, with a tendency to grey in some of the cuts aged for 90 days

IV. CONCLUSIONS

The results of this study confirm the possibility of managing “à la carte” postmortem aging. Depending on the marketing system, professionals are able to adapt the aging duration for each muscle, which would enable them to reach their objectives in terms of consumer satisfaction. Aging the LD for up to 60 days really improved its tenderness and, at the end of this period, the muscle reached 95% of its potential tenderness. Aging for up to 90 days did not, however, provide real added value in terms of tenderness as much as the bad tastes that began to appear. Current aging practices in France (15 days ± 6 on average, according to the National Survey of Beef Tenderness in France) do not enable optimum tenderness of LD to be expressed.

ACKNOWLEDGMENT

The support of Interbev and FranceAgriMer is gratefully acknowledged.

REFERENCES

1. 1. Dransfield E., Zamora F. (1997). Optimization of tenderization, aging and tenderness. Meat Sci. 36, 105-121

2. Tatum J.D., Belk K.E., George M.H., and Smith G.C. (1999). Identification of quality managment practices to reduce the incidence of retail beef tenderness problems: development and evaluation of a prototype quality system to produce tender beef. J; Anim. Sci. 77:2112-2118.

3. Normand J., Rubat E., Evrat-Georgel C., Turin F., Legrand I., Tribot Laspière P., Denoyelle C. (2010). A national survey of beef tenderness in France. ICoMST Proc., 56th International Congress of Meat Science and Technology.

4. Gruber S.L., Tatum J.D., Scanga J.A., Chapman P.L., Smith G.C., Belk K.E. (2006). Effects of postmortem aging and USDA quality grade on Warner-Brazler shear force values of seventeen individual beef muscles. J Anim Sci 84: 3387-96

5. Tribot Laspière P., Evrat-Georgel C, Cartier P. (2008) Aging time effect tenderness of 5 beef muscles provided by steers and dairy cows. ICoMST Proc., 54th International Congress of Meat Science and Technology.

6. King D.A., Wheeler T.L., Shackelford S.D., Pfeiffer K.D., Nickelson R. and Koohmaraie M. (2009) Effect of blade tenderization, aging time, and aging temperature on tenderness of beef longissimus lumborum and gluteus medius. J Anim Sci 87: 2952-2960

7. Denoyelle C., Lebihan E. (2003). Intramuscular variation in beef tenderness. Meat Sci. 66:241-247.