# Effect of aging time on tenderness and colour stability of modified-atmosphere packaged beef from mature cows during shelf life.

**Pérez-Juan M. [1], Vitale M. [2], Lloret E. [2], Arnau J.[2], Realini C.E. [2]**

[1] IRTA/Carcass and Meat Quality, Finca Camps i Armet, Monells (Girona), Spain.
[2] IRTA/Engineering and Food Process, Finca Camps i Armet, Monells (Girona), Spain.

*Abstract*— **Eight Friesian mature cows were used to evaluate the effect of aging time on tenderness and colour stability of beef in modified-atmosphere packaging (MAP) during shelf life. Loins were removed from each carcass at 24 h post-mortem, and cut into three pieces assigned to 0, 6, and 21 days of ageing. After each ageing time, loin sections were cut into 3 cm steaks, packaged individually using MAP (80 % $O_2$: 20% $CO_2$) and tenderness and color stability were evaluated at 0, 3, 6, and 9 d of simulated retail display. Initial toughness was lower for beef aged for 21 d compared with beef aged for 6 and 0 d, which did not differ. Beef aged for 0, 6, and 21 d showed 17, 35, and 12% decrease in shear force over the 9 d of display, respectively. Shear force after 9 days of display was similar for beef aged during 21 and 6 d, and lower than unaged beef. At 9 d of display in MAP, beef aged for 21 d showed higher lightness, and lower redness and yellowness than unaged beef and beef aged for 6 d, which did not differ. Meat discoloration (R630-R580) was higher for beef aged for 21 d compared with the other ageing times, with a mean value (6.25) lower than the proposed threshold for consumer acceptability. Ageing for 6 d tend to improve beef tenderness with similar colour stability to unaged beef, while ageing for 21 d decreased colour stability reducing beef shelf life in MAP**.

*Keywords*— **ageing, MAP, shelf life.**

## I. INTRODUCTION

During post-mortem ageing, muscle structures become looser because of degradation of myofibrillar and cytoskeletal proteins as well as intramuscular collagen [1]. When purchasing meat, consumers judge its quality mainly by means of the colour of its surface and they prefer the bright red oxymyoglobin ($MbO_2$) [2,3]. However, $MbO_2$ is easily discoloured to brown metmyoglobin (MetMB) that limits the retail storage time and occurs substantially before microbial spoilage [3]. Modified atmosphere packaging (MAP) used for fresh meat usually contains 70-80% oxygen to encourage oxymyoglobin formation [4,5]. The aim of this work was to evaluate the effect of ageing time under vacuum on tenderness and colour stability of modified-atmosphere packaged (MAP) beef from mature cows during shelf life.

## II. MATERIAL AND METHODS

### A. Samples preparation

Eight Spanish Holstein cows of 375±7 kg carcass weight and 6±3 years age in average were used for this trial (EUROP conformation=R and fatness grade 3-4).

At 24h *post-mortem*, *Longissimus dorsi* muscles (LD) were divided into three sections, vacuum packaged in OSB3050 bags (Cryovac, Sealed Air Corporation, Duncan, USA), and aged for 0, 6, and 21 days at 2±1°C. After each ageing time, LD muscle sections were cut into 3 steaks (3cm) that were individually packaged in high barrier plastic materials, BFT1523-50 trays and LID 3050 top film (both from Cryovac, Sealed Air Corporation, Duncan, USA), using a 80%$O_2$:20% $CO_2$ gas mixture (Carburos Metálicos, Barcelona, Spain) and a semiautomatic traysealing machine (SMART 500, ULMA Packaging, Oñati, Spain). After packaging, all trays were displayed randomly in a retail case (EURO LX334, ISA, Perugia, Italy) at 4±1°C during 9 days.

### B. Instrumental colour measurements

Lightness (L*), redness (a*) and yellowness (b*) were measured using a Minolta CM-2002 spectrophotometer using illuminant D65 and a 2° standard observer in the CIELAB color space

(Commission Internationale del'Eclairage, 1976). Meat discoloration was determined by reflectance difference between 630nm (maximum of the oxidized myoglobin) and 580 nm (max. of the oxygenated myoglobin) [6].

### C. Tenderness

Steaks were cooked to 71ºC at the core (in preheated oven at 200ºC) and allowed to cool to room temperature for 1.5 hours. Six cores (Ø1x3 cm) were removed per steak and sheared across the muscle fibers using a texture analyzer Alliance RT/5 (MTS Systems Corp., Eden Prairie, MN, USA) equipped with a Warner-Bratzler blade with crosshead speed set at 2 mm/s.

### D. Statistical analysis

Data were analyzed using the GLM procedure of SAS (SAS Inst. Inc., Cary NC) including loin position as a block effect, animal and ageing time in the model. Variables were analyzed as repeated measures and least squares means were generated and separated using the PDIFF option of SAS, with significance determined at P<0.05.

## III. RESULTS

### A. Colour

Colour appearance is the most important sensory attribute of fresh meat for retail sale [2]. The effect of ageing time on L* is shown in Table 1.

Ageing time had no significant effect on L* at the begining of display (0d). At 3 days of storage, beef aged for 21 d was lighter ($L^*_{3d}$=44.70) than beef aged for 6d ($L^*_{3d}$=36.7) and unaged meat ($L^*_{3d}$=33.74). At 6 days of storage, meat aged 0 and 21 days was lighter ($L^*_{6d}$~41) than meat aged for 6 days ($L^*_{6d}$=35.71). At 9 days of storage, the 21 d aged meat was lighter ($L^*_{9d}$=51.74) than unaged and 6d aged meat.

Table 1. Effect of ageing time (0, 6 or 21 days) on L* during retail display (0, 3, 6 and 9 days).

| | **Display time (days)** | | | |
|---|---|---|---|---|
| **Ageing (days)** | **0d** | **3d** | **6d** | **9d** |
| **0** | 34.14 | 33.74$^c$ | 40.05$^a$ | 41.00$^b$ |
| **6** | 36.00 | 36.07$^b$ | 35.71$^b$ | 41.51$^b$ |
| **21** | 36.24 | 44.70$^a$ | 42.46$^a$ | 51.74$^a$ |
| **SE** | 1.45 | 0.64 | 1.33 | 1.19 |

Means within the same column with different letters differ ($P$ < 0.05). SE: standard error.

The effect of ageing time on a* is shown in Table 2. At 0d of storage, aged meat was more red ($a^*_{0d}$=22.50 and $a^*_{0d}$=21.87, aged 6 and 21d respectively) than unaged meat ($a^*_{0d}$=19.45). However, at 3, 6 and 9 days of storage, beef aged for 21 d showed the lowest values for a* ($a^*_{3d}$=19.71, $a^*_{6d}$=17.83 and $a^*_{9d}$=11.69).

Table 2. Effect of ageing time (0, 6 or 21d) on a* during retail display (0, 3, 6 and 9 days).

| | **Display time (days)** | | | |
|---|---|---|---|---|
| **Ageing (days)** | **0** | **3** | **6** | **9** |
| **0** | 19.45$^b$ | 23.69$^a$ | 19.96$^b$ | 18.75$^a$ |
| **6** | 22.50$^a$ | 24.61$^a$ | 24.43$^a$ | 20.13$^a$ |
| **21** | 21.87$^a$ | 19.71$^b$ | 17.83$^c$ | 11.69$^b$ |
| SE | 0.42 | 0.45 | 0.46 | 0.53 |

Means within the same column with different letters differ ($P$ < 0.05).SE: standard error.

The effect of ageing time on b* is shown in Table 3. At 0d and 3d of display, unaged meat was less yellow ($b^*_{0d}$=1.45 and $b^*_{3d}$=4.40) *vs*. 6d and 21d aged meat ($b^*_{0d}$~5 and $b^*_{3d}$~7). Ageing had no significant effect on yellowness at 6 d of display. At 9d of display, 21 d aged meat had lower b*values ($b^*_{9d}$=2.63) than 0d and 6d aged meat ($b^*_{9d}$~7).

Table 3. Effect of ageing time (0, 6 or 21d) on b* during retail display (0, 3, 6 and 9 days).

| Ageing (days) | Display time (days) 0 | 3 | 6 | 9 |
|---|---|---|---|---|
| **0** | 1.45±0.77[b] | 4.40±0.82[b] | 6.35±0.84 | 7.27±0.80[a] |
| **6** | 5.72±0.58[a] | 6.72±0.60[a] | 5.82±0.62 | 7.17±0.59[a] |
| **21** | 4.53±0.65[a] | 7.46±0.68[a] | 6.63±0.70 | 2.63±0.67[b] |

Means within the same column with different letters differ ($P < 0.05$).

## B. *Discoloration*

The effect of ageing time on discolouration (R630-R580) is shown in Table 4. The lower the R630-R580 value, the higher the meat discolouration. At 0d of display, the R630-R580 value was lower for unaged meat ($R630\text{-}R580_{0d}$=12.46) *vs.* aged meat ($R630\text{-}R580_{0d}$=16.67 and $R630\text{-}R580_{0d}$=17.31 for 6d and 21d aged meat, respectively). At 3 and 6d of display, there were no differences in meat discolouration due to ageing time. However, at 9 days of display, meat aged for 21d showed the highest discolouration ($R630\text{-}R580_{9d}$=6.25).

Table 4. Effect of ageing time (0, 6 or 21d) on discolouration (R630-R580) during retail display time (0, 3, 6 and 9 days).

| Ageing (days) | Display time (days) 0 | 3 | 6 | 9 |
|---|---|---|---|---|
| **0** | 12.46±1.33[b] | 15.55±1.59 | 14.92±0.93 | 12.93±1.54[a] |
| **6** | 16.67±0.88[a] | 14.84±1.05 | 15.53±0.61 | 14.40±1.02[a] |
| **21** | 17.31±0.88[a] | 15.00±1.05 | 14.17±0.61 | 6.25±1.02[b] |

Means within the same column with different letters differ ($P < 0.05$).

## C. *Instrumental texture*

The effect of ageing time on instrumental texture is showed in Table 5.

Table 5. Effect of ageing time (0, 6 or 21d) on instrumental texture (WBSF, N) during retail display (0, 3, 6 and 9 days).

| Ageing (d) | Display time (d) 0 | 3 | 6 | 9 |
|---|---|---|---|---|
| **0** | 42±2[a] | 35±3[a] | 34±4[a] | 35±3[a] |
| **6** | 41±3[a] | 33±4[ab] | 32±4[ab] | 27±4[ab] |
| **21** | 27±2[b] | 24±3[b] | 22±3[b] | 24±3[b] |

Means within the same column with different letters differ ($P < 0.05$).

Initial toughness was lower for beef aged for 21 d ($WBSF_{0d}$=27N) compared with beef aged for 6 and 0d, ($WBSF_{0d}$= 41N and 42N, respectively) which did not differ. Shear force after 9 days of display was similar for beef aged during 21 and 6 d ($WBSF_{9d}$= 24N and 27N, respectively), and lower than unaged beef ($WBSF_{0d}$=35N). Beef aged for 0, 6, and 21d showed 17, 35, and 12% decrease in shear force over the 9 d of display, respectively.

# IV. DISCUSSION

Colour appearance is the most important sensory attribute of fresh meat for retail sale [2]. Maria et al., (2003,[7]) studied the effect of 7d and 14d of ageing. Ageing decreased the redness and yellowness which accompanied the natural discoloration of fresh meat from red to brown [8]. Results from the present study also showed a decrease in redness and yellowness in meat aged for 21d, but not in meat aged for 6 d.

A value of R630-R580=12.5 is considered as the threshold value for consumer acceptability [9,10]. At 9d of display time, R630-R580 values were still above 12.5 for 0 and 6d aged beef, indicating a longer shelf life than 9d [11]. However, meat discoloration at 9d of display was higher for beef aged for 21d, with a mean value (6.25) lower than the proposed threshold for consumer acceptability, indicating that beef shelf life was reached within 6-9d of display.

Beef from mature carcasses is generally perceived to be less tender than that from young animals [12]. However, unaged beef from mature cows in the present study was unusually tender with shear force values that were lower than those reported by other authors. Lowe et al., (2004,[13]) found for Friesian cull cows values of 70 N in steaks aged for 20 h, and Allen et al., (2009,[14]) found values of shear force of 48.34 N in Holstein cull cows after 14 d of ageing. The effect of ageing on increasing beef tenderness is well documented [15-17]. In this study, despite the low initial WBSF values, ageing improved beef tenderness reaching shear force values below the proposed industry threshold of 40.20 N [18].

## V. CONCLUSION

Ageing for 6d tend to improve beef tenderness with similar colour stability in MAP to unaged beef, while ageing for 21d increased beef tenderness but decreased colour stability reducing beef shelf life in MAP.

## ACKNOWLEDGMENT

This research was supported by a ProSafeBeef project grant under the European Commission Sixth Framework Programme (Food-CT-2006-36241). Authors thank to Carburos Metálicos, (Barcelona, Spain) for the gas supply.

## REFERENCES

1. Purslow PP (2005) Intramuscular connective tissue and its role in meat quality. Meat Sci 70(3):435-447.
2. Djenane D, Sanchez-Escalante A, Beltran JA, Roncales P (2001) Extension of the retail display life of fresh beef packaged in modified atmosphere by varying lighting conditions. J Food Sci 66(1):181-186.
3. Pietrasik Z, Dhanda JS, Shand PJ, Pegg RB (2006) Influence of injection, packaging, and storage conditions on the quality of beef and bison steaks. J Food Sci 71(2):S110-S118.
4. Grobbel JP, Dikeman ME, Hunt MC, Milliken GA (2008) Effects of packaging atmospheres on beef instrumental tenderness, fresh color stability, and internal cooked color. J Anim Sci 86(5):1191-1199.
5. Limbo S, Torri L, Sinelli N, Franzetti L, Casiraghi E (2010) Evaluation and predictive modeling of shelf life of minced beef stored in high-oxygen modified atmosphere packaging at different temperatures. Meat Sci 84(1):129-136.
6. Gatellier P, Mercier Y, Juin H, Renerre M (2005) Effect of finishing mode (pasture- or mixed-diet) on lipid composition, colour stability and lipid oxidation in meat from Charolais cattle. Meat Sci 69(1):175-186.
7. Maria GA, Villarroel M, Sanudo C, Olleta JL, Gebresenbet G (2003) Effect of transport time and ageing on aspects of beef quality. Meat Sci 65(4):1335-1340.
8. Faustman C and Cassens RG (1990) Influence of aerobic metmyoglobin reducing capacity on color stability of beef. J Food Sci 55(5):1278-1283.
9. Gatellier P, Hamelin C, Durand Y and Renerre M (2001) Effect of a dietary vitamin E supplementation on colour stability and lipid oxidation of air- and modified atmosphere-packaged beef. Meat sci 59(2):133-140.
10. Gatellier P, Mercier Y and Renerre M (2004) Effect of diet finishing mode (pasture or mixed diet) on antioxidant status of Charolais bovine meat. Meat Sci 67(3):385-394.
11. Isdell E, Allen P, Doherty AM and Butler F (1999) Colour stability of six beef muscles stored in a modified atmosphere mother pack system with oxygen scavengers. Int J Food Sci Tech 34(1):71-80.
12. Xiong YL, Mullins OE, Stika JF, Jie C, Blanchard SP and Moody WG (2007) Tenderness and oxidative stability of post-mortem muscles from mature cows of various ages. Meat Sci 77(1):105-113.
13. Lowe TE, Devine CE, Wells RW and Lynch LL (2004) The relationship between postmortem urinary catecholamines, meat ultimate pH, and shear force in bulls and cows. Meat Sci 67(2):251-260.
14. Allen JD, Ahola JK, Chahine M, Szasz JI, Hunt CW, Schneider CS, Murdoch GK and Hill RA (2009) Effect of preslaughter feeding and ractopamine hydrochloride supplementation on growth performance, carcass characteristics, and end product quality in market dairy cows. J Ani Sci 87(7):2400-2408.
15. Campo MM, Santolaria P, Sanudo C, Lepetit J, Olleta JL, Panea B and Alberti P, (2000) Assessment of breed type and ageing time effects on beef meat quality using two different texture devices. Meat Sci 55(4):371-378.
16. Dransfield E. (1994) optimization of tenderization, aging and tenderness. Meat Sci 36(1-2):105-121.
17. Sanudo C, Macie ES, Olleta JL, Villarroel M, Panea B, Alberti P, (2004) The effects of slaughter weight, breed type and ageing time on beef meat quality using two different texture devices. Meat Sci 66(4):925-932.
18. Huffman KL, Miller MF, Hoover LC, Wu CK, Brittin HC and Ramsey CB (1996) Effect of beef tenderness on consumer satisfaction with steaks consumed in the home and restaurant. *J. Anim Sci.*, 74, 91-97.