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Colour stability of steaks from large beef cuts aged under vacuum or high oxygen modified atmosphere

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ABSTRACT

The aim was to investigate the effects of ageing large beef cuts, 10-cm-long *longissimus dorsi* (LD) and 4-cm-long *semimembranosus* (SM), on colour stability during subsequent storage of steaks in air for 5 days. Ageing solely in high oxygen modified atmosphere (MA, 80% O_2 + 20% CO_2) for 5 or 10 days or ageing in vacuum for 5 or 15 days followed by high oxygen MA for 5 or 10 days were compared with ageing in vacuum for 5, 15 and 25 days at 4 °C. Ageing system and ageing time influenced colour stability. For short ageing times, 5 to 10 days, large beef cuts could be aged in high oxygen MA without negative effect on colour stability compared with vacuum ageing. Longer ageing times, 15 to 25 days, decreased colour stability. Then vacuum ageing was preferable to ageing in vacuum for 5 or 15 days followed by high oxygen MA.

1. Introduction

Retail packaging of meat in modified atmosphere (MA) with high oxygen content is used to provide a stable bloomed red meat colour, which is attractive to the consumer. An oxygen content of at least 55% is needed to prolong colour stability (Jacobsen & Bertelsen, 2000) and 70–80% is widely used in MA packaging. Inclusion of 20–30% CO_2 prolongs the shelf life by inhibiting bacterial growth (McMillin, 2008). The prolonged colour stability in MA compared with in air depends on the formation of a thick layer of oxymyoglobin (OxyMb) at the meat surface that masks the underlying metmyoglobin (MetMb) layer (Jeremiah, 2001). In addition, oxygen partial pressures above that which is present in air have been observed to retard MetMb formation and preserve OxyMb and redness (Jeremiah, 2001). On the other hand, vacuum packaging provides a stable purple colour of deoxymyoglobin (DeoxyMb) for a long time if residual oxygen is avoided in the package (Jeremiah, 2001). Large primal beef cuts are usually aged in vacuum before cutting and retail packaging in high oxygen MA or in vacuum skin pack or trays for exposure to air.

It is known that ageing time *postmortem* affects colour and colour stability of beef due to changes in oxygen consuming (Atkinson & Follet, 1973; Bendall & Taylor, 1972; Lanari & Cassens, 1991; Madavi & Carpenter, 1993; Tang et al., 2005a) and metmyoglobin reducing activities of the meat (Bekhit & Faustman, 2005; Tang et al., 2005b). It is further known that colour stability varies between different muscles (McKenna et al., 2005; Seyfert et al., 2006). *M. longissimus dorsi* (LD) has very high colour stability, whereas *M. semimembranosus* (SM) has lower colour stability.

The present study was part of a project on the effect on meat quality of ageing large beef cuts in high-oxygen MA for retail sale without repackaging. Results on water-holding capacity, instrumental tenderness, proteolysis and protein degradation were reported in Lindahl, Lagerstedt, Ertbjeg, Sampels, and Lundström (2010). In addition measurements on colour stability in air were performed referring to what may happen when the packages with large beef cuts are opened and cut into steaks. Part of the meat may be stored in the refrigerator for several days. The objective of this study was to evaluate colour stability in air of steaks cut from large pieces of LD (10 cm-long) and SM (4 cm-long) after ageing solely in high oxygen MA or in vacuum followed by high oxygen MA compared with ageing solely in vacuum. In addition, the general effect of ageing time on colour stability was evaluated. The study was performed on the same material as reported in Lindahl et al. (2010).

2. Material and methods

2.1. Animals, sample collection and treatments

Ten young bulls of Swedish Holstein breed were slaughtered on the same day according to standard routines at a commercial slaughterhouse. All animals (age 14–17 months) came from one farm and had the same feeding regime, *ad libitum* access to silage and barley. All carcasses were electrically stimulated (low voltage, 30 s). The weight of the carcasses ranged from 288 to 315 kg and the EUROP classification varied from O^- to O^+ and with a EUROP fatness score from 2^+ to 3^+. The carcasses were hung by the Achilles tendon and

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kept in a chilling room at 4 °C overnight. During commercial cutting, the fore- and hind-quarters were separated between ribs 10 and 11. LD and SM from both sides of the carcasses were excised at 1 day *postmortem* and stored at 4 °C until packaging for the different treatments at 2 days *postmortem*.

LD and SM from both sides of the carcasses were divided into five 10-cm-long pieces (LD) or 4-cm-long pieces (SM) giving 10 pieces per animal (Fig. 1). The five pieces of LD or SM were numbered 1 to 5 irrespective of whether they came from the left or the right side of the carcass. Treatments were distributed along the LD and SM locations according to an extended Latin Square design with randomized order of location on the first animal and of animal number. Thus LD and SM from all 10 animals and all the five locations were represented in each ageing system, and each LD and SM location was represented by two animals.

Ten different treatments (ageing systems) were included in the study according to Table 1: no ageing, ageing solely in vacuum (V) for 5, 15 or 25 days, ageing in high oxygen modified atmosphere (M) with 80% O_2 + 20% CO_2 for 5 or 10 days or ageing in V for 5 or 15 days followed by M for 5 or 10 days. The maximum time in M was set to mimic the storage times used by the Swedish industry today. The samples were aged in darkness in a chilling room at 4 °C.

After each ageing time, steaks (2 cm thick) were cut and the newly cut inside surfaces, which were not exposed to the high oxygen MA during ageing, were directed upside and exposed to air. The steaks were wrapped with oxygen-permeable PVC-film NORM PACK 115 45-1 (Teampac AB, Tyresö, Sweden) and stored in air at 4 °C for 5 days in darkness. Samples for analysis of pigment content were taken just inside the steaks for colour measurements (Lindahl et al., 2010).

2.2. Colour measurements

The colour was measured using a Minolta CM-2500d spectrophotometer (Minolta Co, Ltd, Osaka, Japan) with specular reflectance excluded, 8 mm diameter measuring aperture, illuminant D65, 10° Standard Observer and CIE colour scale (CIE, 1976). The measuring aperture was covered with a glass plate, and the instrument was calibrated against a white plate ($L^*=97.29$, $a^*=-0.07$, $b^*=0.12$). The average of four measurements across the surface was used. The colour was measured through the covering film. Colour stability was assessed by repeated colour measurements on the same steaks after blooming for 1 h and 3 h and then daily during 5 days of storage in air. The relative content of deoxymyoglobin (DeoxMb) was estimated by the ratio K/S474 to K/S525, the relative content of OxyMb by the ratio K/S610 to K/S525 and the relative content of MetMb by the ratio K/S572 to K/S525 (Hunt et al., 1991; Mancini, Hunt, & Kropf, 2003). The instrument measured the reflectance between 360 and 740 nm at 10-nm intervals. K/S ratios at wavelengths not given by the instrument (474, 525, 572 nm) were calculated using linear interpolation of the reflectance values. The K/S ratios decrease when the relative content of the corresponding myoglobin form increases and the K/S ratios were therefore transformed to get the right impression when looking at the figures. The K/S ratio of OxyMb was transformed to [1 − (ratio K/S610 to KS525)] and the K/S ratio of MetMb was transformed to [2 − (ratio K/S572 to K/S525)].

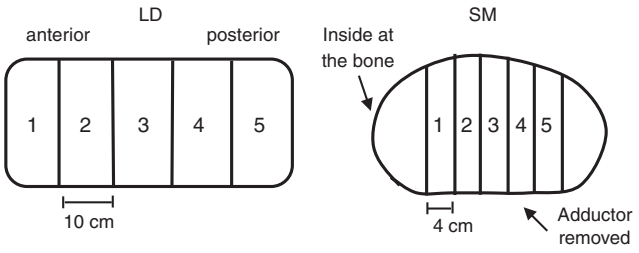

Fig. 1. Sampling of *M. longissimus dorsi* (LD) and *M. semimembranosus* (SM).

Table 1
Experimental design. 10-cm-long pieces of *M. longissimus dorsi* and 4-cm-long pieces of *M. semimembranosus* (cut 2 days *postmortem*) were not aged or aged in different ageing systems, vacuum and/or high oxygen modified atmosphere (MA) at 4 °C.

Ageing system	Sample name	Ageing time (days)		
		Vacuum	MA	Total
No ageing	V0M0	0	0	0
Ageing solely in vacuum	V5M0	5	0	5
	V15M0	15	0	15
	V25M0	25	0	25
Ageing solely in MA	V0M5	0	5	5
	V0M10	0	10	10
Ageing in vacuum followed by MA	V5M5	5	5	10
	V5M10	5	10	15
	V15M5	15	5	20
	V15M10	15	10	25

2.3. Pigment content

Pigment content was analysed using the Nit409 method (Trout, 1991) with minor modification. Sub-samples of 3 g of muscle were homogenised with 30 ml of 0.04 M potassium phosphate buffer pH 6.5 using an Ultra Turrax for 40 s. The samples were kept on ice and filtered through a Whatman 42 filter paper (Whatman International Ltd, Maidstone England). Next, 1 ml of the supernatant was mixed with 3 ml of the potassium phosphate buffer pH 6.5, 1.4 ml of 0.15 M TritonX-100 solution and 100 µl of 0.065 M sodium nitrite solution. The samples were shaken and kept at room temperature (20 °C) for 1 h. The absorbance of the oxidised pigment (MetMb) was measured at 410 nm using a spectrophotometer (Shimadzu UV-2401PC, Kyoto, Japan). The pigment content was calculated from a standard curve with myoglobin from sperm whale (Serva Feinbiochemica, Heidelberg, Germany) and expressed as mg myoglobin/g wet muscle.

2.4. Statistical analysis

Statistical analysis was carried out with the Statistical Analysis System version 9.1 (SAS Institute Inc., Cary, NC, USA). The MIXED procedure was applied when calculating least squares means (LSM) and standard errors (SE). The statistical model for colour parameters included ageing system, storage time and their interaction as fixed effects and animal as random effect. Three different models were used depending on the variables studied. A model including storage time as fixed effect and animal as random effect was used for analysis of differences between storage times in air within each ageing system. The option PDIFF with Bonferroni adjustment for multiple comparisons was used to calculate *P* values when testing differences between LSMs at the fixed storage times 3 h or 5 days using a model including ageing system as fixed effect and animal as random effect. The model for differences in myoglobin content between LD and SM included muscle as fixed effect and animal as random effect. Differences in colour parameters between LD and SM within each ageing system at the fixed storage times 3 h or 5 days were evaluated only within non-aged meat and samples aged solely in vacuum. A model including muscle as fixed effect and animal as random effect was used. *P* values ≤ 0.05 were considered significant.

3. Results

3.1. Pigment content

The myoglobin content was 5.65 (SE = 0.69) mg/g in LD and 6.07 (SE = 0.88) mg/g in SM muscle, with no significant difference between the muscles ($P=0.245$).