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Effects of oxygen concentration on the sensory evaluation and quality indicators of beef muscle packed under modified atmosphere

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Abstract

Beef steaks are commonly displayed under high oxygen concentrations in modified atmosphere packs (MAP) in order to promote colour stability. Such conditions, however, may also cause quality deterioration through lipid oxidation and decreased tenderness. The objective of this study was to investigate the effects of oxygen concentration (0%, 10%, 20%, 50% and 80%) on the quality of MAP beef steaks (*M. longissimus dorsi*). Steaks were stored at 4 °C for 15 days and tested for lipid and protein oxidation, heme iron, colour, oxymyoglobin concentration, tenderness and sensory acceptability (up to day 12) for the resulting cooked meat. Sensory panellists expressed a preference for steaks stored in packs containing 50% oxygen, despite detecting oxidised flavours under these conditions. This could be the result of adaptation to, or familiarity with, oxidised flavours by panellists.

Keywords: Beef; MAP; Lipid oxidation; Protein oxidation; Tenderness; Sensory analysis

1. Introduction

Over the past number of years much research has focused on the influence of modified atmosphere packaging (MAP) on meat quality attributes and the purchasing preferences of consumers (Carpenter, Cornforth, & Whittier, 2001; Jayasingh, Cornforth, Brennand, Carpenter, & Whittier, 2002). Many attempts have been made to reduce pigment and lipid oxidation in meats through treatments with, for instance, antioxidants and MAP (Carpenter, O'Grady, O'Callaghan, O'Brien, & Kerry, 2007; O'Grady, Maher, Troy, Moloney, & Kerry, 2006). MA packs usually contain mixtures of two or three gases: O_2 (to enhance colour stability), CO_2 (to inhibit microbiological growth), and N_2 (to maintain pack shape) (Jakobsen & Bertelsen, 2000; Kerry, O'Grady, & Hogan, 2006; Sørheim, Nissen, & Nesbakken, 1999). High O_2 concentrations promote the formation of oxymyoglobin (OxyMb), the cherry red form of myoglobin (O'Grady, Monahan, Burke, & Allen, 2000). However, this may impact negatively on the oxidative stability of muscle lipids and lead to the development of undesirable flavours (Estevez & Cava, 2004; Rhee & Ziprin, 1987). A distinctive off-flavour develops rapidly in meat that has been precooked, chilled-stored and reheated. The term warmed-over-flavour (WOF) has been adopted to identify this flavour deterioration (Renerre & Labadie, 1993). Oxidation of polyunsaturated fatty acids not only causes the rapid development of meat rancidity, but also affects colour, nutritional quality and texture of beef (Kanner, 1994).

Lipid and protein oxidation are closely associated deteriorative processes occurring in meat, although relatively little is known about the repercussions of the latter on the quality of meat products (Estevez, Ventanas, & Cava, 2006; Rhee & Ziprin, 1987). Previous work by Decker, Xiong, Calvert, Crum, & Blanchard (1993) reported that protein oxidation can affect the quality of meat and meat products. Oxidation might play a role resulting in the loss of enzyme activity, solubility and formation of protein

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complexes and non-enzymatic browning products (Mercier, Gatellier, & Renerre, 2004) and could be linked to meat tenderness. Rowe, Maddock, Lonergan, and Huff-Lonergan (2004) found that increased oxidation of muscle proteins early post-mortem could have negative effects on meat tenderness. Recent studies have indicated that storage under high O_2 atmospheres can result in a decrease in beef tenderness (Torngren, 2003). As such, the requirements for colour stability must be balanced against the deteriorative action of lipid oxidation.

The objective of the present study was to investigate the relationship between O_2 concentration in MAP beef muscle and a number of indicators: lipid and protein oxidation, colour stability, concentration of heme and non-heme iron, tenderness values and sensory attributes of cooked meat quality.

2. Materials and methods

2.1. Reagents

All chemicals used in the course of this study were 'AnalaR' grade and obtained from Sigma–Aldrich Ireland Ltd., Airton Road, Tallaght, Dublin 24, Ireland.

2.2. Sampling and packaging

Beef steak, *M. longissimus dorsi* (LD) muscle, was obtained from a local slaughterhouse. Muscles were removed from Hereford heifers which were less than 30 months of age. Muscles were cut into uniform ~2.54 cm thick steaks. LD muscles (8 × 5 kg) were removed from the left side of carcasses. Samples were taken from carcasses that were stored for approximately 2 weeks at 4 °C post-slaughter and hung by the achilles tendon. All analyses were performed up to 15 days of retail display with the exception of sensory analysis which was performed up to 12 days. One steak was used for sensory analysis, one steak for Warner–Bratzler Shear Force (WBSF) and a third steak was divided into 4 portions to perform the instrumental/chemical analyses (oxymyoglobin concentration, lipid oxidation, protein oxidation and heme iron concentration). Duplicate samples were measured in triplicate for all analysis. Steaks were vacuum packed (polyamide/polyethylene bags) and stored at 4 °C until required for modified atmosphere packaging (MAP). Steaks stored under MAP were placed in polystyrene/EVOH/polyethylene trays and heat sealed with laminated barrier film (polyolefin) with (oxygen transmission rate of 3 $cm^3/m^2/24$ h at STP). A Gustav Mueller VS 100 modified atmosphere packaging machine was used to pack samples with different combinations of gases: O_2, N_2, CO_2 (Table 1).

Vacuum packed samples were packed using a Webomatic C50 vacuum packaging system (Bochum, Germany). All samples were placed in a refrigerated display cabinet at 4 °C ± 1 °C under fluorescent light (616 LUX) for 15 days.

Table 1
Modified atmosphere packaging treatments (gas mixtures)

Atmosphere	O_2 (%)	N_2 (%)	CO_2 (%)
O_20	0	80	20
O_210	10	70	20
O_220	20	60	20
O_250	50	30	20
O_280	80	0	20

2.3. Measurement of muscle pH

Muscle pH was measured using a portable pH meter (Mettler Toledo, MP 125, Switzerland). The pH of the beef steaks was taken by making a small hole in the muscle and inserting a glass spear electrode (Mettler Toledo, MP 125) approximately 0.5 cm into the muscle. Values were documented to ensure that steaks had normal pH levels and were suitable for packaging (i.e. pH < 5.8).

2.4. Colour analysis

The surface colour of beef steaks was measured according to the CIE L^* a^* b^* colour system using a Minolta CR 300 colorimeter (Minolta Camera Co. Ltd., Osaka, Japan). The chroma meter was calibrated on the Hunterlab colour space system using a white tile (C: $Y = 93.6$, $x = 0.3130$, $y = 0.3193$), (Minolta calibration plate). Six readings were taken per sample on each measurement day at each time point of retail display.

2.5. Lipid oxidation

Lipid oxidation was measured by the method of Siu and Draper (1978) and expressed as 2-thiobarbituric acid reactive substances (TBARS) in mg malondialdehyde kg^{-1} meat.

2.6. Measurement of oxymyoglobin

Oxymyoglobin in *M. longissimus dorsi* beef steaks was determined spectrophotometrically according to the method of Krzywicki (1982).

2.7. Measurement of protein oxidation

Protein oxidation was measured according to the method outlined by Oliver, Ahn, Moerman, Goldstein, & Stadtman (1987), with the modification of Vuorela et al. (2005). Determination of protein oxidation comprised two procedures: (a) carbonyl content and (b) protein quantification. (a) Meat samples (2 g) were homogenized in 20 ml of 0.15 M KCl buffer using an Ultra Turrax T25 (Staufen, Germany) homogenizer for 60 s. An aliquot of homogenate (0.045 ml) was transferred to a 2 ml Eppendorf vial and 1 ml of 10% trichloroacetic acid was added. Samples were centrifuged for 5 min at 5000*g* and the supernatant removed. For procedure (a) 1 ml of 2 M HCl