Meat Science 145 (2018) 16–22

Contents lists available at ScienceDirect

Meat Science

journal homepage: www.elsevier.com/locate/meatsci

The effect of temperature during retail display on the colour stability of CO pretreated vacuum packaged beef steaks

Lauren Anne Van Rooyen[a,b], Paul Allen[a], Eimear I. Gallagher[b], David I. O'Connor[b,*]

[a] Teagasc Food Research Centre, Food Quality and Sensory Department, Ashtown, Dublin 15, Ireland
[b] Dublin Institute of Technology, School of Food Science and Environmental Health, Cathal Brugha Street, Dublin 1, Ireland

ARTICLE INFO

Keywords:
Carbon monoxide
Colour stability
K/S ratios
Meat quality
Packaging
Vacuum packaging

ABSTRACT

The effect of CO pretreatments applied to beef striploin steaks (*Longissimus thoracis et lumborum,* LTL) prior to vacuum packaging and display temperature on colour stability, shelf life and tenderness was determined. Steaks were exposed to 5% CO, 60% CO_2 and 35% N_2 for 3 (CO3), 5 (CO5) or 7 (CO7) h, followed by 28 days display at 2 °C (good industry practice) or 6 °C (mild abuse). CO5 was the optimum exposure time as it induced the desirable colour while not retaining the bright colour, irrespective of display temperature. *K/S* ratios confirmed that CO pretreatment did not mask spoilage and could be more sensitive than colour parameters at monitoring discoloration as colour was not retained. Exposure to CO did not have any negative effect on meat quality attributes, while mild temperature abuse (6 °C) increased purge loss and decreased pH.

1. Introduction

Consumer discrimination against discoloured meat products is one of the leading causes of meat waste for retailers in Europe, North America and Industrialized Asia (FAO, 2016).This is mainly due to consumers relying on colour as a cue for perceived quality (Issanchou, 1996) and association with discoloured meat as unwholesome (Faustman & Cassens, 1990) or unsafe to consume (Grebitus, Jensen, & Roosen, 2013). Adding to this, the global population is forecasted to continue to increase from 7.5 billion to 9.7 billion by 2050, driving a greater demand for meat supplies. For these reasons, it is vitally important to reduce or remove meat wastage altogether in order to ensure global food supply and a sustainable future for our growing population.

Packaging can play a key role in preventing meat waste by maintaining an attractive colour and avoiding unnecessary consumer discrimination. Innovations in meat packaging technologies which ensure the meat has a desirable "cherry" red colour and support increasing consumer demand and expectation for more tender, high quality meat may be a potential solution (Van Rooyen, Allen, & O'Connor, 2017). One packaging technology in particular which could meet the above criteria is the application of low concentrations of carbon monoxide (CO) as a pretreatment prior to vacuum packaging. CO has the ability to act as colour enhancer and coupled with vacuum packaging extends the shelf-life and avoids any negative quality issues associated with high oxygen modified atmosphere packaging (MAP) including tenderness (Van Rooyen, Allen, Crawley, & O'Connor, 2017). CO is currently used as a primary packaging gas at low concentrations (0.4%) or as a secondary packaging gas in the USA (FDA, 2004). In Canada, New Zealand and Australia CO is permitted to be used as a processing aid or secondary packaging gas (Federal Register of Legislative Instruments, 2014; USDA-FSIS, 2016). However, globally the regulation of the use of CO in meat packaging varies and within the EU CO is currently prohibited. This was at least partly due to concerns that CO may be misused to mask meat spoilage for meat that has previously been stored under inappropriate storage conditions such as elevated temperatures (European Commission, 2001). However, recently Van Rooyen, Allen, Crawley, and O'Connor (2017) showed that the CO pretreatment exposure time can be reduced to 5 h to enhance colour while allowing discolouration to occur by the use-by-date. Therefore, colour could continue to be used as an indicator of freshness and wholesomeness as the colour would not mask meat spoilage or falsely mislead consumers. However, if this technology was to be implemented within the meat industry further research is necessary to determine the stability of CO pretreatments, in the case of mild temperature (6 °C) abuse, which may occur due to mishandling during distribution or storage, as temperature has a direct influence on colour stability (O'Keefe & Hood, 1980). It is therefore necessary to establish that CO pretreatment would not mask meat spoilage under these conditions.

Quantifying the amount of carboxymyoglobin (COMb) present on the meat surfaces at the end of the shelf-life may be useful to confirm that CO does not mask spoilage by retaining the bright colour. However, quantifying COMb using reflectance methodology is difficult

* Corresponding author.
E-mail address: david.i.oconnor@dit.ie (D.I. O'Connor).

https://doi.org/10.1016/j.meatsci.2018.05.017
Received 2 August 2017; Received in revised form 10 April 2018; Accepted 22 May 2018
Available online 24 May 2018
0309-1740/

as currently there is no direct method to quantify COMb (AMSA, 2012). The method of Krzywicki (1979) uses the reflectance values on the meat surface to calculate the proportion of myoglobin in the redox form, however this method does not account for the presence of COMb (AMSA, 2012). The percentages of myoglobin in its various forms can also be calculated from *K/S* ratios (absorption (*K*) and scattering coefficients (*S*)) following Stewart, Zipser, and Watt (1965). The entire meat surface is converted to each of the myoglobin redox states and these standards along with the *K/S* ratios to determine the percentage of each pigment present at the meat surface. However, unrealistic data are often observed with values lower than 0% or > 100% (Mancini, Hunt, & Kropf, 2003). Mancini et al. (2003) reported that adjusting the data may be useful to obtain more realistic results, however there has been no research to support the benefits of this. Therefore *K/S* ratios are useful for estimating myoglobin redox forms and give a more detailed understanding of surface meat colour stability. Surface reflectance data are converted to *K/S* ratios by using the light absorbance (*K*) and scattering properties (*S*) using the Kubelka-Munk equation as it relates to reflectance, R ($(1 - R)^2 \div 2R$) which results in more linear data (Mancini et al., 2003). Additionally, *K/S* ratios may be a useful method to detect the amount of COMb, metmyoglobin (MMb) or deoxymyoglobin (DMb) present on the meat surface (AMSA, 2012), especially at the end of storage to confirm that CO does not mask spoilage. There are also no reports on the effect of 5% CO pretreatments prior to vacuum packaging beef steaks on the reflectance and absorbance properties of meat surfaces. Therefore, the objective of this study was to investigate the effect of CO exposure time and temperature on the colour stability and quality attributes including pH, purge loss, COMb layer, tenderness and cooking loss of beef striploin (LTL) steaks during storage (2 °C or 6 °C).

2. Materials and methods

2.1. Sample preparation and pretreatment procedure

CO pretreatments were carried out as described in Van Rooyen, Allen, Crawley, and O'Connor (2017) with minor modifications. Four boneless beef loins (*Longissimus thoracis et lumborum,* LTL) of normal pH 5.43–5.56 from two Charolais-cross (CHX) heifers aged 21–29 months of age were obtained from a commercial meat producer for each of the three replicates repeated on three separate occasions. Steaks were cut (25 mm thick, 285.2 g – 388.0 g) at 6–8 days post-mortem from each of the four loins (blocks) and one steak from each loin was allocated to treatments randomly. Steaks were vacuum packaged (New Diamond Vac J-V006 W, Heavy Duty Automatic Vacuum Machine, Jaw Feng Machinery Co., Ltd, Taiwan; vacuum pressure < 0.01 Torr held for 32 s) in a pouch (5-layer coextruded film with PA/Tie/PE/Tie/PE (OTR: < −70 cm^3 O_2/m^2/24 h at 23 °C and 50% RH, Versatile Packaging, Ltd., Castleblayney, Co. Monaghan, Ireland) for 1 h to allow reduction of the myoglobin to occur and limit the formation of oxymyoglobin. Samples were then exposed to a gas mixture with CO (5% CO, 60% CO_2 and 35% N_2) or without CO (Control) (60% CO_2 and 40% N_2) for 3 (CO3 and CONT3), 5 (CO5 and CONT5) or 7 h (CO7 and CONT7), and stored at 2 °C. They were then removed and immediately individually vacuum packed (Product # S303, Synpac, PA/PE (OTR: < 38 cm^3 O_2/m^2/24 h at 23 °C and 0% RH, Synpac Ltd., Saxon way, Priory Park West, Hessle, East Yorkshire, UK). This was placed under retail display at 2 °C which is good industry practice or 6 °C which is mild abuse for 28 d under continuous fluorescent lighting (Meat - Fluorescent Touchcoat T5F18WT8 176 Foodstar Meat Toughcoat, Havells Sylvania Fixtures UK, Ltd) (2115 lx) to simulate retail conditions. Temperature was recorded every five minutes using data-loggers (Lascar EasyLog-USB, Lascar Electronics Ltd., Salisbury, SP5, UK).

2.2. Instrumental colour measurement

Surface colour measurements, reflectance and absorbance readings were performed using a HunterLab UltraScan Pro (Hunter Associates Laboratory., Inc., Reston, VA) with a viewing port of 25 mm and illuminant D_{65}, 10° with the specular component excluded. Calibration was carried out using a white standard tile (L = 100) and a light trap (L = 0) covered with the vacuum packaging film to eliminate any effect on the colour readings of packaged steaks. Triplicate measurements were recorded at representative locations on the meat surface for each steak. Chroma ($C^* = (a^{*2} + b^{*2})^{1/2}$) values were calculated using CIE a* (redness) and b* (yellowness) measurements. Three surface reflectance and absorbance measurements were also measured from 400 to 700 nm (5 nm interval). Surface reflectance data at 474, 525, 572 nm were calculated by linear interpolation. *K/S* ratios were determined using the Kubelka-Munk equation to obtain each myoglobin redox form with better linearity (AMSA, 2012). Deoxymyoglobin (DMb) $(K/S_{474})/(K/S_{525})$, Metmyoglobin (MMb) $(K/S_{572})/(K/S_{525})$ and Carboxymyoglobin (COMb) $(K/S_{610})/(K/S_{525})$ were calculated. Reference standards for 100% MMb, DMb, COMb were prepared (AMSA, 2012). Surface colour analysis was measured at days 0, 2, 10, 21 and 28.

2.3. Measurement of pH

The pH of each treated steak was measured after removal from the vacuum package using a glass probe pH electrode (Thermo Scientific pH meter 420A, Orion Research Inc.) and triplicate measurements were recorded for each steak. pH measurements were recorded after storage (2 °C or 6 °C) on days 0, 2, 10, 21 & 28.

2.4. Carboxymyoglobin (COMB) depth

Carboxymyoglobin (COMb) layer was measured according to the method of (Raines & Hunt, 2010) to determine the COMb layer on each treated sample. Treated steaks were removed from the vacuum packages after storage, cut in half vertically and the depth of the transition point of COMb to DMb was immediately recorded using a digital caliper (Draper Expert, PVC 150 D, Draper Tools Ltd., Hampshire, SO53, UK). Triplicate measurements were recorded in separate locations on each sample and averaged to determine the depth of the COMb layer. COMb layer measurements were measured after storage (2 °C or 6 °C) on days 0, 2, 10, 21 and 28.

2.5. Purge loss

Purge loss, also known as drip loss or water holding capacity, was determined according to the method of Krause, Sebranek, Rust, and Honeyman (2003) as an index of loss of water from the meat. The weight of each unopened treated steak package was recorded. Each sample was then removed from the package and blotted dry and re-weighed to determine weight loss. Purge loss measurements were recorded after storage (2 °C or 6 °C) on days 0, 2, 10, 21 and 28. The percentage purge loss was determined according to the following equation as a percentage of the weight of the steak in the package. With this formula the weight of the package is counted as purge loss.

$$\%\text{Purge loss} = \frac{(\text{Weight of package + steaks}) - (\text{Weight of steaks}) \times 100}{(\text{Weight of package + steaks})}$$

2.6. Determination of cooking loss

Determination of cooking loss was according to the method of Shackelford et al. (1991) and as described Van Rooyen, Allen, Crawley, and O'Connor (2017). Cooking loss was determined on samples that had been displayed at 2 °C or 6 °C for 0, 7, 14, 21 and 28 days. Control