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Effect of high-oxygen atmosphere packaging on oxidative stability and sensory quality of two chicken muscles during chill storage

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ABSTRACT

The oxidative stability and sensory quality of chicken breast (*m. pectoralis*) and thigh (*m. peroneus longus*) stored in high-oxygen modified atmosphere (MAP-O_2), non-oxygen modified atmosphere (MAP-N_2), or vacuum for up to 9 days at 5 °C were investigated. Protein thiol concentration in breasts and thighs decreased significantly between 5 and 9 days storage in MAP-O_2 compared to non-oxygen storage, and resulted in myosin heavy chain disulfide cross-links. Thiol loss and protein cross-link formation were more pronounced in thighs compared to breasts, and a similar tendency was seen for the formation of secondary lipid oxidation products. However, while breast stored in MAP-O_2 clearly scored lower in tenderness and higher in rancidity compared to breast in non-oxygen storage, the effect of MAP-O_2 for the sensory quality of thigh was negligible. These results show that thigh is more suitable for storage in MAP-O_2 than breast, indicating that the negative effect MAP-O_2 may have on the oxidative stability and sensory quality of meat varies between different muscles.

1. Introduction

High-oxygen modified atmosphere packaging (MAP) is the packaging method of choice for fresh meat in Denmark and other western countries as it prolongs the shelf-life of meat by reducing microbial growth and preserving red meat color compared to traditional aerobic packaging (McMillin, 2008). However, the oxidative processes are accelerated due to the high concentration of oxygen and prolonged storage times (Asensio, Ordonez, & Sanz, 1988). Hence, MAP typically reduces the eating quality and nutritional value of meat or meat products by inducing lipid and protein oxidation during storage (Lund, Lametsch, Hviid, Jensen, & Skibsted, 2007; Skibsted, Mikkelsen, & Bertelsen, 1998).

Lipid oxidation generates off-flavors through the breakdown of lipid hydroperoxides into volatile aldehydes and ketones and causes rancidity in meat (Skibsted et al., 1998). Protein oxidation causes protein modifications, which impair the textural properties of the meat as reviewed by Lund, Heinonen, Baron, and Estévez (2011). Meat tenderness is one of the most commonly used parameters for the evaluation of meat quality by the consumers. Thus, meat texture is a highly important factor for the meat industry to consider during the production of meat. Tenderness is associated with the structural integrity of the myofibrillar proteins, which

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constitute primarily myosin and actin. Compromising the structural integrity of the myofibrillar proteins leads to altered textural properties (Xiong, 2000). Lund et al. (2007) demonstrated how the formation of protein disulfide cross-linking of the myosin heavy chain (MHC) correlated with a reduced tenderness in *longissimus dorsi* from pork during chill storage in high-oxygen MAP. Following, a similar phenomenon has been reported for beef (Zakrys-Waliwander, O'Sullivan, O'Neill, & Kerry, 2012), and lamb (Kim, Bødker, & Rosenvold, 2012) stored in high-oxygen modified atmospheres. Cross-linking of myofibrillar proteins is believed to reduce meat tenderness by causing a strengthening of the myofibrillar structure in meat stored under high-oxygen MAP. This hypothesis has been supported by a study showing that the breaking strength of single muscle fibers extracted from bovine *longissimus dorsi* stored in high-oxygen MAP is increased compared to storage in vacuum packaging (Lund, Christensen, Fregil, Hviid, & Skibsted, 2008).

Disulfides are one of the most common oxidation products of thiols, and these protein cross-links may be formed both intra- and intermolecularly. The oxidation of thiols may proceed by two electron oxidation or by radical-mediated reactions (Nagy & Winterbourn, 2010), and may be initiated by hypervalent myoglobin species or Fenton reagents to generate disulfide cross-links (Galaris, Cadenas, & Hochstein, 1989). Reports demonstrate that thiols in the tail region of the myosin molecule are more reactive than in the head region (Xiong, Park, & Ooizumi, 2009), which may be due to the position of the thiol groups being directly across from each other in the tail part of MHC. Thiols are extremely prone to oxidation, and studies have shown that reaction rates of cysteine and methionine with the oxidant hypochlorous acid exceed those of the amino acid residues lysine or arginine by 10^4- or 10^6 order of magnitudes, respectively (Pattison & Davies, 2001, 2006). Hence, oxidation of thiols and the resulting formation of protein disulfides are important factors to consider when evaluating oxidation-mediated protein modifications in meat.

With regard to chicken, primarily two cuts, breasts and thighs, are sold at retail in high-oxygen MAP. The present study aimed to investigate the effect of high-oxygen MAP on protein oxidation in two different chicken cuts, breast (*m. pectoralis*) and thigh (*m. peroneus longus*), during chill storage in order to determine differences in oxidation potential and sensory quality between the two cuts. Protein oxidation was evaluated by the quantification of protein thiols and by the generation of protein disulfide cross-links in the myofibrillar protein fractions. Further, lipid oxidation was evaluated by TBARS and the extent of protein and lipid oxidation was compared to the concentration of myoglobin and the endogeneous antioxidant vitamin E in the two chicken cuts. All chemical analyses were discussed in relation to the organoleptic characteristics evaluated by a trained sensory panel.

2. Materials and methods

2.1. Reagents

Reagent-grade chemicals and distilled-deionized (MilliQ) water were used throughout.

2.2. Preparation, packaging, and storage of chicken breasts and thighs

Breast and thighs were collected on the day of slaughter from a Danish slaughter house. The meat was vacuum packed and transported to the Danish Meat Research Institute (Roskilde, Denmark), where it was MA-packed for retail in 500 g trays using a T200 Traysealer (Multivac, Vejle, Denmark). One sample refers to one tray containing either two breasts or four thighs. The trays were sealed and packed in MAP-O_2 (80% O_2 and 20% CO_2), MAP-N_2 (80% N_2 and 20% CO_2), or under vacuum. Tray and film for MAP-O_2 or MAP-N_2 were M71-51A black PP (oxygen permeability: 12.4 cm^3/tray/24 h/atm) with Toplex HB L PP 60 (oxygen permeability: 3 cm^3/m^2/24 h/atm) or M71-51A black MAPET (oxygen permeability: 0.63 cm^3/tray/24 h/atm) with TOPSEAL.PET.MAP.P.B.AF.62 (oxygen permeability: <0.3 cm^3/m^2/24 h/atm), respectively, all obtained from Færch Plast (Holstebro, Denmark). Vacuum bags were SR 200 × 270 PA/PE 90 (oxygen permeability: 40–50 cm^3/m^2/24 h/atm) from LogiCon Nordic A/S (Kolding, Denmark). The gas composition in both MAP-O_2 and MAP-N_2 was measured in minimum six empty trays before the chicken was packed. The oxygen concentration for chicken thigh and breast packed in MAP-O_2 at day 9 was 74.1 ± 0.2 and 79.2 ± 0.4, respectively as detected by Check Mate 9900 (PBI Dansensor, Ringsted, Denmark). No oxygen was detected in MAP-N_2 at day 9.

Three 0-day samples of breasts and thighs were kept in vacuum and stored at −80 °C until analysis. The MA-packed breasts and thighs were stored at 5 °C in a walk-in-cooler for 2, 5, or 9 days with display light (1200 lx) for 12 h each day. The visual appearance of the samples was documented by photography immediately after the package was opened, and psychotropic count was determined by incubation in PCA for 10 days at 6.5 °C. For the chemical analyses three replicates of each sample were vacuum packed and stored at −80 °C until analysis. For the sensory analyses five replicates of each sample were brought to the sensory laboratory for analysis on the same day. For all chemical as well as sensory analyses, the muscles *m. pectoralis* or *m. peroneus longus* were dissected from breast or thigh, respectively, and used throughout.

2.3. TBARS analysis

The thiobarbituric reactive substances (TBARS) were determined by TBARS analysis according to Vyncke (1970) and Sørensen and Jørgensen (1996). Aliquots of 5 g breast (*m. pectoralis*) or thigh (*m. peroneus longus*) were homogenized in 15 ml 7.5% trichloroacetic acid (TCA) with 0.10% propylgallate and 0.10% EDTA for 45 s using an Ultra Turrax T-25 Homogenizer (Bie and Berntsen A/S, Denmark). Afterwards, the sample was filtered (Whatman™ Filter Paper Circles, 589/2, diameter 125 mm, GE Healthcare, Germany) and 5.0 ml of the filtrate was mixed with 5.0 ml 20 mM thiobarbituric acid (TBA), incubated in a 100 °C water bath for 40 min, and cooled on ice until room temperature. The absorbance was measured at 532 and 600 nm at room temperature. Results are expressed as 2-thiobarbituric reactive substances (TBARS) in μmol MDA (malondialdehyde equivalents)/kg dry matter using a standard curve and are presented as means ± sd of three replicates unless otherwise stated in the figure text.