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Effect of oxygen concentration in modified atmosphere packaging on color and texture of beef patties cooked to different temperatures

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ABSTRACT

Patties were made from raw minced beef after storage for 6 days in modified atmosphere (0, 20, 40, 60, and 80% oxygen) to study the combined effect of oxygen concentration and cooking temperature on hardness and color. Increased oxygen concentrations generally led to larger ($P < 0.01$) thiobarbituric acid-reactive substances (TBARS) values, greater ($P < 0.01$) loss of free thiols and more formation of cross-linked myosin heavy chain. Hardness of cooked patties was generally lower ($P < 0.01$) without oxygen. Premature browning of cooked patties was observed already at a relative low oxygen concentration of 20%. The internal redness of cooked patties decreased ($P < 0.05$) with increasing oxygen concentrations and increasing cooking temperatures. Mean particle size (D(3,2)) of homogenized cooked meat generally increased ($P < 0.05$) with increasing cooking temperatures and increasing oxygen concentrations, and particle size was correlated ($r = 0.80$) with hardness of cooked patties.

1. Introduction

In modified atmosphere packaging (MAP), oxygen serves to maintain bright red oxymyoglobin in fresh red meat. Increased concentrations of oxygen generally increase color stability (Bartkowski, Dryden, & Marchello, 1982; Jakobsen & Bertelsen, 2000). However, a high level of oxygen also promotes lipid oxidation (Jayasingh, Cornforth, Brennand, Carpenter, & Whittier, 2002; Kim, Huff-Lonergan, Sebranek, & Lonergan, 2010; O'Grady, Monahan, Burke, & Allen, 2000), which contributes to rancidity in meat and discoloration (Faustman, Sun, Mancini, & Suman, 2010). In addition, high-oxygen packaging increases the incidence of premature browning in cooked meats (Seyfert, Hunt, Mancini, Kropf & Stroda, 2004; Seyfert, Mancini & Hunt, 2004; Suman et al., 2005). Premature browning describes a condition in which meat or meat products appear fully cooked (brown) while they have not reached a safe internal temperature sufficient to kill pathogens that might be present (Hague et al., 1994). Boqvist, Fernström, Alsanius, and Lindqvist (2015) thus reported that the survival of *Escherichia coli* O157:H7gfp+ was higher in hamburgers made from minced meat stored in 80% oxygen than in atmospheric condition when using a visual color score to decide doneness. Therefore, efforts to inform consumers about premature browning in meat packaged in high oxygen concentrations are needed as many consumers continue to evaluate the degree of doneness in meat products by the internal color despite advice from food safety authorities on using thermometers to measure the core temperature (Phang & Bruhn, 2011).

Protein oxidation has in recent years been investigated in modified atmosphere packaged meat in relation to eating quality. High concentration of molecular oxygen leads to extensive protein oxidation and the consequences of protein oxidation are mainly reduction of tenderness and juiciness (Lund, Heinonen, Baron, & Estevez, 2011). The effects of protein oxidation on textural properties have so far been more studied in intact meat, possibly due to less importance of tenderness in minced meat products like patties. However, the mincing process increases the surface area and may therefore cause greater oxygen exposure and protein oxidation, leading to undesirable or unacceptable eating quality.

While some studies have revealed the effect of high oxygen packaging on meat quality (Clausen, Jakobsen, Ertbjerg, & Madsen, 2009; Jayasingh et al., 2002; Lagerstedt, Lundström, & Lindahl, 2011; Lund, Lametsch, Hviid, Jensen, & Skibsted, 2007), much less is known on the relationship between the oxygen concentration and the oxidation of lipids, and especially the oxidation of proteins. We hypothesize that oxidative conditions promote protein oxidation which in turn affects the particle size and premature browning. The aim of this study was to examine the effect of oxygen concentration in MAP on lipid and protein oxidation in minced beef and their relationship to premature browning,

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hardness and particle size of patties after cooking to different end-point temperatures.

2. Materials and methods

2.1. Sample preparation

Three batches of minced beef were prepared for this study. Beef shoulder (*triceps brachii* muscle) from Ayrshire bulls was purchased from Heikin Liha Oy (Helsinki, Finland). The average carcass weight was 368 kg. For each batch, around 10 kg of *triceps brachii* muscles from two different animals was used. The muscles were trimmed for visible connective tissue and fat and then cut into small cubes. The meat cubes were then minced in a grinder (LM-5P, Koneteollisuus Oy, Finland) through a plate with pore size of 4.5 mm in diameter. The meat was kept on ice both before and after mincing. Portions of minced beef were collected as day 0 sample, the remaining meat was allocated for five groups (4 packages/group/batch) with different oxygen concentrations (0, 20, 40, 60, and 80%). In addition, each package contained 20% CO_2 to inhibit the microbial growth and the gas composition was balanced with N_2. Food grade gases (BIOGON, AGA, Finland) were used and mixing and sealing were performed on a Multivac D-8941 packaging machine (Sepp Haggenmüller GmbH & Co., Wolferschwenden, Germany). The initial gas composition was regulated with a gas controller (Witt-Gasetechnik D-5810, Witt-Gasetechnik GmbH & Co KG., Witten, Germany) and checked after storage by a Checkmate 9900 O_2/CO_2 instrument (Dansensor, Ringsted, Denmark). Each package contained 200 g of minced meat placed in a plastic tray (K-301, Kreis Pack, Niepruszewo, Poland) and the headspace to meat volume was around 3:1. The packaging bags (product number: 6418055000205) were purchased from a local company (Heino Tukku Oy, Espoo, Finland). The minced meat was distributed evenly on the tray as a thin layer about 1 cm thick. All packages were stored at 3 °C in a walk-in cold room for 6 days and received light of approximately 700 lx for 12 h every day from tubular fluorescent lamps (Osram L 36 W-76 G13 Natura, Osram, Munich, Germany) which were positioned at a distance of about 50 cm above the packages.

After the storage, the minced meat was sampled for determination of color, pH, particle size distribution, SDS-PAGE and thiobarbituric acid-reactive substances (TBARS) values, and free thiol content. After color measurement, the meat was well mixed and then sampled for the other measurements. In addition, two patties of 80 g (diameter about 10 cm, thickness about 12 mm) were prepared from each package by a hamburger maker (Kitchen Craft, Birmingham, UK) and each patty was vacuum packaged. The packaged patties were kept in cold temperature (5 °C) for 1 h and then immersed in water bath and cooked for 1 h at different temperatures (55 °C, 60 °C, 65 °C, and 70 °C). The relative long cooking time was used to ensure that the water bath temperature was reached in the internal part of the patties and to obtain a uniform temperature from the patty surface to center. The cooked patties were sampled for the measurement of internal color, texture and particle size distribution. For SDS-PAGE and particle size analysis, meat samples were stored frozen before measurements.

2.2. pH

About 0.5 g minced beef was homogenized in 5 mL cold solution containing 5 mM sodium iodoacetate and 150 mM KCl. The pH value of the homogenate was measured at room temperature (Jeacocke, 1977).

2.3. Color of minced meat

Color was measured both at day 0 and day 6. At day 0, the minced beef was kept on ice for about 2 h until the color measurement. At day 6, the minced beef was kept at room temperature for 30 min after opening of each package. Color was measured with a Minolta Chroma meter CR-400 (Minolta Camera Co. Ltd., Osaka, Japan) set at D65 illuminant at room temperature. The diameter of measuring aperture was 8 mm. The instrument was calibrated using a white tile (C: Y = 93.6, x = 0.3130, y = 0.3193). For each package, the L* (lightness), a* (redness) and b* (yellowness) values were recorded from three randomly chosen spots on the surface of minced beef.

2.4. Photography and redness of cooked patties

After cooking, patties were dried with paper tissues. A small piece of 2 cm in length was cut from each patty and positioned with the inner part facing upward. These small pieces were kept at room temperature for 1 h and then displayed in a VeriVide color assessment cabinet (Verivide Limited, Enderby, United Kingdom) under light from the lamp 840TL84. Photos of cooked patties were taken by a Canon EOS 40D digital camera. The readings of a* value from the Minolta Chroma meter CR-400 was used to evaluate the internal redness.

2.5. Hardness of patties

Six rectangular shaped samples (2 cm × 2 cm × patty height) were cut from each cooked patty, and then they were compressed with a probe of 6 mm in diameter using a TA.XT *plus* texture analyzer (Stable Micro System Ltd., Godalming, Surrey, UK) fitted with a 5 kg load cell. Each sample was compressed once from the middle in the orientation of patty height. Test speed was 5 mm/s and the target strain was 60%. Peak force (kg) was recorded as hardness.

2.6. Particle size distribution

For preparing the meat homogenates, 1.0 g of meat was homogenized in 15 mL cold buffer (100 mM KCl, 10 mM K_2HPO_4, 10 mM KH_2PO_4, 1.0 mM EDTA, 1.0 mM $MgCl_2$) at 20,500 rpm for 15 s using an Ultra-Turrax T25. Particle size distribution of the meat homogenate was determined by a Mastersizer 3000 (Malvern Instruments Ltd., Malvern, UK) according to Lametsch, Knudsen, Ertbjerg, Oksbjerg, and Therkildsen (2007). Every homogenate was analyzed five times using tap water as dispersant. The refractive index was set to 1.46 and the absorption coefficient to 0.01, and the particles were considered as non-spherical. The volume-surface diameter (D(3,2)) was used to describe the mean particle size.

2.7. TBARS (thiobarbituric acid-reactive substances)

Determination of malondialdehyde (MDA) by thiobarbituric acid (TBA) is one of the most common assays in lipid peroxidation analysis. One molecule of MDA can react with two molecules of TBA with the production of a pink pigment having an absorption maximum at 532 nm (Esterbauer & Cheeseman, 1990). In this study, a sample of 5 g was used to determine the TBARS values as described by Bao and Ertbjerg (2015).

2.8. Free thiol groups

Thiol groups were determined according to Riener, Kada, and Gruber (2002) with some modifications. Briefly, 1.0 g meat was homogenized with 20 mL 5% (w/v) SDS in 0.1 M Tris-HCl (pH 8.0) at 13,500 rpm for 30 s. The homogenates were kept in water bath at 80 °C for 30 min. After cooling down to room temperature, the homogenates were filtered through filter paper (Whatman 1, GE Healthcare). An aliquot of 0.1 mL filtrate was mixed with 0.9 mL of 0.1 M Tris-HCl (pH 8.0) and the mixture was used for determination of protein and thiol content. Protein content was determined by reading the absorbance at 280 nm. Thiol groups were measured by adding 50 μL of 10 mM DTNB/10 mM cystamine reagent to the abovementioned 1 mL mixture. Absorbance