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Effect of MAP, vacuum skin-pack and combined packaging methods on physicochemical properties of beef steaks stored up to 12 days

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ABSTRACT

The physicochemical properties of *M. longissimus lumborum* steaks over 12 days of storage at 2 °C, and under three packaging conditions, were investigated: vacuum skin packaging (VSP); modified atmosphere packaging (MAP), and their combination with semi-permeable inner VSP film (VSP-MAP). Standard gas composition (80% O_2/20% CO_2) was used for MAP and VSP-MAP packaging. CIE L*a*b* color parameters of VSP-MAP samples were similar to those kept in MAP and significantly higher to those stored in VSP. Myoglobin oxidation was more evident in VSP-MAP and MAP samples than in VSP indicating increased oxidation processes. However, storage in MAP resulted in greater lipid oxidation compared both to VSP and VSP-MAP. No differences between treatments were observed in terms of Warner–Bratzler shear force values and drip loss. In general, these results suggest that the combination of VSP and MAP methods may be an efficient way to reduce negative quality changes typical for both systems used separately.

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1. Introduction

Current case-ready beef market offers meat in two leading packaging systems — modified atmosphere packaging (MAP) and vacuum packaging (VP). MAP results in prolonged shelf life compared to aerobic packaging and in a more attractive bright red color due to myoglobin oxygenation (Carpenter, Cornforth & Whittier, 2001), but also increases lipid oxidation rate (Kim, Huff-Lonergan, Sebranek & Lonergan, 2010; Lund, Hviid & Skibsted, 2007). Compared to vacuum storage it also shows increased growth of aerobic spoilage microorganisms (Arvanitoyannis and Stratakos, 2012). MAP gaseous mixture consists of oxygen and carbon dioxide. Oxygen at high concentrations (70–80%) maintains the red color of meat, whereas carbon dioxide at a concentration of at least 20% inhibits the growth of microorganisms by extending the lag phase and generation time (Nassu, Juárez, Uttaro & Aalhus, 2010). Vacuum packaging offers anaerobic conditions inside the package, which leads to further shelf-life extension and provides stable color (Jeremiah, 2001). However, purple color of meat obtained in oxygen-free conditions is not considered as attractive as bright red. This is of major importance since consumer preferences are influenced mostly by color (Mancini and Hunt, 2005). One of the disadvantages of VP is the exudates held in wrinkles formed after air removal. Vacuum skin packaging (VSP) is an advanced type of vacuum packaging which helps to avoid the formation of film wrinkles by making upper film shrink tightly around meat. Meat in VSP is considered more attractive to consumers and is claimed to have longer shelf-life (Vázquez et al., 2004). Nowadays, VSP is becoming a very popular type of case-ready vacuum packaging (Paramithiotis, Skandamis & Nychas, 2009).

Due to several disadvantages of both packaging systems, the market has recently offered another packaging system, commercially called Cryovac® Darfresh® Bloom, which is a combination of MAP and VSP methods. This method is not yet widely used and is founded on the use of a barrier tray and two films: inner oxygen-permeable vacuum skin film and outer barrier film. The injection of gas mixture between these films enables myoglobin oxygenation, vertical exposure in retail sale and aids in minimizing purge cumulation. However, a disadvantage of this system is the need for an oxygen barrier as well as permeable films (Nassu, Uttaro, Aalhus, Zawadski, and Juárez, 2012). Research on this type of packaging system was conducted (Nassu et al., 2012; Zhao, Wells & McMillin, 1994) in terms of beef quality parameters, yet its construction included a vacuum-skin package enclosed in a barrier bag with modified atmosphere. The aim of this study was to investigate the influence of the three abovementioned packaging systems on quality traits of *M. longissimus lumborum* steaks stored up to 12 days.

2. Materials and methods

2.1. Animals, samples and packaging

Animals (twelve *Limousin* × *Holstein Fresian* bulls, aged 16–18 months) were slaughtered according to standard routines at a local slaughter plant. Carcass weight and conformation score (EUROP) as well as fat score (Alderton, Faustman, Liebler, and Hill, 2003; AMSA,

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2012; Arvanitoyannis and Stratakos, 2012; Bağdatli and Kayaardi, 2015; Carpenter, Cornforth, and Whittier, 2001) were recorded at slaughter according to official standards and regulations used in the European Union. Hot carcass weight ranged from 208.0 to 289.6 kg and the EUROP classification varied from R− to O+ with EUROP fatness score from 1+ to 2−. After 72 h post-mortem *Longissimus lumborum* (LL, striploin) muscles were removed from the carcasses, sealed in vacuum bags (polyamide/polyethylene bags) and transported at 2 °C to Warsaw University of Life Sciences for further packaging. Then all muscles were removed from bags, trimmed for connective tissue and external fat, each cut into ten 2.5-cm steaks. Nine steaks were packaged as follows: (i) modified atmosphere packaging (MAP), (ii) vacuum skin packaging (VSP) and (iii) a combination of modified atmosphere and skin packaging (VSP-MAP) for storage over 4, 8, or 12 days. The tenth steak was not packaged, and was assigned 0 days storage. The inner VSP film in VSP-MAP was semi-permeable to oxygen (4000 cm^3/m^2/24 h at STP). Outer packaging materials were made of polypropylene/ethylene vinyl alcohol/polyethylene film with oxygen transmission rate of 2 cm^3/m^2/24 h at standard temperature and pressure. Gas composition used for both MAP and VSP-MAP was 80% oxygen and 20% carbon dioxide and the gas headspace to meat ratio was 2:1. MAP, VSP and VSP-MAP packaging methods were performed in a Sealpac Traysealer M3 (Sealpac, Germany) and Cryovac VS26 (Sealed Air Cryovac, USA). The samples were stored at 2 °C for up to 12 days. Maximum time of storage was set according to storage times currently used in Polish industry.

2.2. Near infrared spectroscopy analysis (NIR) and pH — sample characterization

Near infrared spectroscopy analysis was performed using a NIRFlex Solids N-500 spectrophotometer of spectral range 12,500–400 cm^{-1} in reflectant mode (BUCHI Labortechnik GmbH, Germany) to examine the chemical composition of samples. Results were expressed as percentage of protein, fat, water, connective tissue and ash. Samples (100 g) of meat were homogenized (Buchi B-400 homogeniser, BUCHI Labortechnik GmbH, Germany), placed into a Petri plate and scanned in triplicate at a 32 scanning rate. All three scans of each sample were examined for consistency and then averaged. pH was measured to eliminate meat with pH > 5.8, if any. pH-metric results were obtained with Testo 205 pH-meter (Testo Inc., Germany) equipped with a glass electrode, which was placed directly into the samples (2 cm deep into the steaks).

2.3. Instrumental measurement of color

The surface color of beef steaks was measured by assessing L*, a* and b* values using a Minolta CR 400 colorimeter (Minolta Camera Co. Ltd., Osaka, Japan). The chromameter was calibrated using a white tile (L* = 98.45, a* = −0.10, b* = −0.13; Minolta calibration plate), using an 8 mm aperture, illuminant D65 (6500 K color temperature) at a standard observation angle of 2°. The chroma and hue angle were calculated as $(a^2 + b^2)^{1/2}$ and $Tan^{-1}(b^*/a^*)$, respectively. Ten readings were taken per sample on each measurement day. Color measurements were performed directly after opening the package since consumers buying case-ready packaged beef evaluate its color at the point of sale, with no blooming.

2.4. Drip loss

Drip loss was estimated by weighing the meat on day 0 (M_0) and after removal from package on the appropriate day of measurement (M_n). All samples were gently blotted with tissue paper prior to weighing. Drip loss was expressed as a percentage of the initial weight of the meat:

$$\%\text{driploss} = \frac{M0 - Mn}{M0} \times 100.$$

2.5. Warner–Bratzler shear force and cooking loss

Shear force measurements were performed according to the method by Shackelford et al. (1991) with slight modifications. Steaks were weighed, placed in individual plastic bags and cooked in a convection oven (100% humidity) (KEG 010 K, Küppersbusch Großküchentechnik GmbH, Germany) at 85 °C to an internal temperature of 75 °C, cooled down in tap water of 2–4 °C and stored overnight at 4 °C. Internal temperature was measured with oven thermocouples in two randomly chosen samples during cooking. After removal from bags, steaks were weighed to estimate cooking loss. Subsequently, ten cores (1.27 cm diameter) were cut out from each of the steaks, parallel to the muscle fiber direction. Cores were sheared perpendicular to the muscle fibers using a Warner–Bratzler V-shaped blade attached to a 5 kN load cell of an Instron Universal Testing Machine (Model 5965, Instron Corp., Canton, MA) with a crosshead speed of 200 mm/min. Peak shear force was recorded in newtons. From the ten cores measured, the six showing the shear force values nearest to the mean were used to obtain the mean value for the sample, as recommended by the experimental procedure. Cooking loss was expressed as a percentage of the initial weight of the meat (Mr — raw meat, Mc — cooked meat):

$$\%\text{cookingloss} = \frac{Mr - Mc}{Mr} \times 100.$$

2.6. Lipid oxidation

Lipid oxidation was evaluated using 2-thiobarbituric acid according to protocol by Pegg (2001) with slight modifications. Briefly, 5.0 g meat was homogenized in a 20 ml 20% trichloroacetic acid and 2 ml of 0.5% propyl gallate and 0.5% EDTA solution using an Ultra Turrax (IKA, Germany) for 60 s at 9500 rpm and filtered through Whatman N° 1 paper filter. 2.0 ml of the filtrate was added to 2.0 ml 0.02 M thiobarbituric acid (TBA) and incubated at 100 °C in a water bath for 40 min. Absorbance was measured at 532 nm after cooling. Results were expressed as 2-thiobarbituric acid reactive substances (TBARS) in mg malondialdehyde/kg of meat using a standard curve prepared from tetrametoxypropane. Duplicate measurements were made for each meat sample and mean values were used for statistical analysis.

2.7. Percentage contents of myoglobin redox forms

Percentage contents of oxymyoglobin (OxyMb), deoxymyoglobin (DeoMb) and metmyoglobin (MetMb) were evaluated by the method described by Krzywicki (1982) using wavelengths and calculations modified by Tang, Faustman & Hoagland (2004). Thin slices of 1 g of muscle were homogenized with 10 ml of 0.04 M phosphate buffer (pH = 6.8, 2 °C) for 1 min, left at 2 °C for 1 h and centrifuged at 14,000*g* for 45 min. Absorbance was recorded at 525 nm (isosbestic point), 503 nm (metmyoglobin, MetMb), 557 nm (deoxymyoglobin, DeoxyMb) and 582 nm (oxymyoglobin, OxyMb) using a Shimadzu UV/VIS 1800 spectrometer (Shimadzu Corp., Tokyo, Japan) and used to calculate the ratios of myoglobin forms.

2.8. Microbial analysis — total viable counts (TVC)

Microbiological analysis of beef steaks was carried out on every measurement day. Three random meat samples were taken from each treatment and sent to an accredited laboratory where measurements were

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