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Master bag low-oxygen packaging system: Quality evolution of ground beef patties during storage, blooming and display presentation

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ABSTRACT

Case-ready ground beef patties have been packed using a low-oxygen master bag packaging system with oxygen scavengers consisting in: storage for 10 days in low oxygen master bag (0.5 °C), blooming for different times and display life in air for 2 days (5 °C). The kinetics of blooming was studied as well as the effect of a PVC stretch film (with an O_2TR – oxygen transmission rate – equal to 20,000 $cm^3\,m^{-2}\,24\,h^{-1}$ (23 °C, 0% RH, 1 bar of pO_2) with or without perforation on myoglobin oxygenation and color changes. During storage in master bags, the scavengers allowed the progressive conversion of surface oxymyoglobin into deoxymyoglobin through the reversible formation of metmyoglobin (transient discoloration). The microflora shifted from aerobic to anaerobic with a predominance of lactic acid bacteria. The concentration of *Brochotrix thermosphacta* remained constant over the entire storage period. The removal of the trays from the master bag and the subsequent storage in air allowed the blooming of the meat within 60 min. The high O_2TR value of the stretched PVC guaranteed rapid oxygen exchange, whereas the presence of the perforation did not contribute to a further increase in the superficial oxygenation. The quality decay during the display life was comparable to that of samples never stored in master bags. In conclusion, the use of low oxygen master bags was able to prolong the storage time on ground beef patties ensuring the current shelf life achieved with traditional packaging system.

1. Introduction

Patties made with ground beef are very common products on retail stores due to their ease of use and versatility. Ground meat is more perishable than whole or sliced meat because the cut and the grinding process expose the deep sterile tissues to atmospheric oxygen, and the nutrients are spread out from cells, so they are available for microorganisms. Furthermore, the higher exposed surface enhances the oxidative and degradative reactions. For these reasons, ground meat is generally classified as one of the most hygienically risky foods because it could be a good habitat for food-poisoning microorganisms dangerous for humans (e.g., *Listeria monocytogenes*) (Kotula & Kotula, 2000; Noriega, Laca, & Diaz, 2010).

The selection of the packaging solution plays an important role: it has to guarantee the safety of the product but at the same time it favors its shelf life extension, reducing the food waste especially at retail and consumer levels. Different packaging systems could be chosen while distributing ground beef patties.The most common solution used for patties packaging consists of non-barrier trays overwrapped with stretch films having an O_2 transmission rate (O_2TR) > 10,000 $cm^3\,m^{-2}\,24\,h^{-1}$, 23 °C. At 4 °C, the shelf life of these patties is no longer than 3 days (John et al., 2004).

To improve the redness stability of patties, barrier packages containing a modified atmosphere (MA) with up to 80 kPa O_2 can be used (Jayasingh, Cornforth, Brennand, Carpenter, & Whittier, 2002; Ho, Huang, & McMillin, 2003), as well as up to 0.4 kPa of carbon monoxide (CO) (Brooks et al., 2008; Jeong & Claus, 2010), with the complementary presence of carbon dioxide (CO_2) which has a bacteriostatic effect). The shelf life may be prolonged for 10 days or more, but the high O_2 levels promote rancidity (Smiddy, Papkovskaia, Papkovsky, & Kerry, 2002; Limbo, Torri, Sinelli, Franzetti, & Casiraghi, 2010), premature browning (Hunt, Sorheim, & Slinde, 1999; Grobbel, Dikeman, Hunt, & Milliken, 2008a), and sensory decay (Jayasingh et al., 2002; Grobbel, Dikeman, Hunt, & Milliken, 2008b; Kim, Huff-Lonergan, Sebranek, & Lonergan, 2010; Zakrys-Waliwander, O'sullivan, Allen, O'Neil, & Kerry, 2010; Celia Resconi et al., 2012).

To reduce oxidations, low-O_2 packaging systems are used, such as vacuum packaging and low-oxygen MAs (Grobber, Dikeman, Smith, Kropf, & Milliken, 2006). The latter extend the distribution

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life of meat by 5–10 days depending on the cut and the headspace of the package, which must be minimized to avoid residual O_2. The drawbacks of this solution consist of the color change of deoxygenated meat (purple hues), which can be perceived by consumer as negative, and the risk of permanent discoloration (brown hue) caused by low O_2 residuals (Brandon, Beggan, Allen, & Butler, 2009; Sorheim, Westad, Larsen, & Alvseike, 2009).

The aim of this work was to study the effects of a master bag low-O_2 packaging system on ground beef patties quality. It seeks to extend the shelf life of the product distributed it in the purple state and then markeed it in the bright red state. Multiple case-ready units of patties packed with non-barrier materials are inserted inside a barrier master bag containing O_2 scavengers and low-O_2 MA, and then stored at approximately 0–1 °C. Before being displayed on shelves, the product is placed into contact with atmospheric O_2, which enables the blooming (i.e., pigment oxygenation) of meat which reaches the bright red color typical of fresh meat and familiar for the consumers.

The evolution of quality indexes during storage, blooming and display life will be discussed, focusing on the kinetics of oxygenation after the anoxic storage.

2. Materials and methods

2.1. Meat

Meat from *Semitendinosus* muscle (average weight 4 kg, pH 5.6–5.8) of pure Italian breed "*Piemontese*" (age 15–18 months, 9–10 days post mortem) was cut (Cutter K 40, Seydelmann, Germany) and ground using an industrial meat grinder (Model 346SS Manual Feed Grinder, Biro, Ohio, USA) with a 4 mm plate. After grinding, 150 g patties (minimum 90 g/100 g lean) were formed with a patty-forming machine (Planus 869, CRM, Italy). All of these operations were carried out in the back of a retailer in Milan (Italy).

2.2. Experimental

Ground beef patties were provided from a local grocery store already packed into expanded polystyrene (EPS) trays (27 × 14 × 2 cm) and overwrapped with a stretch PVC film with an O_2TR of approximately 22,000 $cm^3\ m^{-2}\ 24\ h^{-1}$ at 23 °C, 0% RH and 1 bar of pO_2. Each tray contained 2 patties for a total weight of approximately 300 g. The headspace of the tray was reduced as much as possible, and the stretch film was in direct contact with the upper surface of the patties. Four trays were inserted inside a master bag (60 × 40 cm) of coextruded material (PE/EVOH/PE) with an O_2TR of less than 1 $cm^3\ m^{-2}\ 24\ h^{-1}$ at 23 °C and 1 bar pO_2. The master bag packaging was performed with the use of a CVP machine (Downers grove, IL), applying a double vacuum-flush cycle under the following conditions: vacuum 7 s, flushing 0.8 s for the first cycle; vacuum 6.5 s, flushing 3 s for the second cycle. The sealing time was 2.7 s. The composition of the atmosphere inserted into the master bag was 30 kPa carbon dioxide (CO_2) and 70 kPa nitrogen (N_2). Additionally, two iron-based preactivated oxygen scavengers (FreshPax® CR, Multisorb Technologies, nominal capacity 800 cm^3) were inserted inside each master bag before sealing.

A total of 132 trays divided into 33 master bags were prepared as described in Table 1. The master bags were divided into three batches to perform analyses after 4, 8 and 10 days of storage. All the master bags were maintained in the dark at 0.5 ± 0.5 °C, and when each master bag was opened, the blooming phase and display life were monitored for 0.5, 1, 3 and 5 h at 3 ± 1 °C and for 48 h at 4 ± 2 °C. To evaluate the blooming phase, after the master bag was opened, the PVC stretch film of half of the packages was manually perforated using a toothed wheel to allow free atmospheric exchange during the blooming time. Each film had 12 holes with a 0.36 ± 0.07 mm diameter for a total perforated area of 0.407 mm^2 (density of perforation 1 hole/40.5 cm^2). The holes sizes were verified through optical microscope analyses carried out on 10 samples of film after wrapping (Nikon 110 Eclipse ME600, Nikon Instruments spa, Italy).

Table 1
Number of master bags and trays used in the experimental plan.

Scheduled analysis time	Number of master bags (MBs)	Number of trays
4 days of storage in MB	11	44
- Before blooming		4 (UP)[a]
- Blooming kinetics		32 (16 UP+16P)[a,b]
- Display life		8 (UP)
8 days of storage in MB	11	44
- Before blooming		4 (UP)[a]
- Blooming kinetics		32 (16 UP+16P)[a]
- Display life		8 (UP)
10 days of storage in MB	11	44
- Before blooming		4 (UP)[a]
- Blooming kinetics		32 (16 UP+16P)[a]
- Display life		8 (UP)

[a] UP = unperforated PVC film; P = perforated PVC film.
[b] Blooming kinetics: total number of trays used to describe the kinetics of blooming. At each blooming time, 8 trays (4UP + 4P) from different MBs were used.

Meat that had never been stored in the master bag was used as a control for the display life analyses, using at least 4 trays for each display time (1 and 2 days).

2.3. Color evaluation and visual appearance

The color evaluation of patties was carried out after each storage time in the master bags (before and after blooming) and during storage in the retail display case in air at 4 ± 2 °C for 48 h. Color measurements were carried out with a hand-held tri-stimulus colorimeter (Minolta Chroma Mether CR-210, Minolta, Osaka, Japan) with an 8 mm viewing port, 2° standard observer and a C illuminant source. Before each measurement, the apparatus was calibrated on the Hunterlab color space system using a white ceramic tile (Minolta calibration plate, Y = 92.6, x = 0.3136, y = 0.3196). The color was described as the Hue angle (H°, expressed as arctan b^*/a^*) and Chroma (C*, expressed as $(a^2 + b^2)^{1/2}$) indexes.

Full-color images of patties were acquired using a Canoscan-LiDE 200 scanner (Canon Inc., Tokyo Japan) at 300 dpi resolution in pre-standardized conditions (black box over imposing) and stored as PNG files (Riva, Campolongo, Avitabile Leva, Maestrelli, & Torreggiani, 2005).

2.4. Estimation of myoglobin states

Reflectance spectra (in the range of 380–780 nm) were obtained from two different locations of the patties covered with a cling film using a UV–vis spectrophotometer (Lambda 650, PerkinElmer, Italy) equipped with an integrating sphere (110 mm diameter, incident reflectance angle of 8 degrees, PerkinElmer, Italy). The reflectance spectra were recorded by placing the samples onto the reflectance port of the integrating sphere with the specular door opened. The reflectance values of the difference in myoglobin oxidation states were estimated at specific wavelengths and converted to K/S values (K is the absorption coefficient, and S is the scattering coefficient). The K/S values were used to quantify the proportions of oxymyoglobin (OxyMb), deoxymyoglobin (DeoxyMb) and metmyoglobin (MetMb) and were calculated using specific wavelengths for fresh meat color in accordance with the AMSA guidelines (AMSA, 2012). The ratios and the wavelengths