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Determination of critical levels of residual oxygen to minimize discoloration of sliced packaged Norwegian salami under light display

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ABSTRACT

Discoloration of sliced packaged salami is contributing to rejection of the product, food waste and economical loss. A combination of residual O_2 in the headspace of packages and light is causing photooxidation and deterioration of colour. The aim of this study was to establish maximum tolerable concentrations of residual O_2 in packages of salami slices with 100% N_2 under light display at 4 and 20 °C. Salami sausages had variable inherent O_2 consumption rate. Storage of salami in 1% O_2 in darkness did not induce discoloration. The upper limits for O_2 for avoiding discoloration under light were variable in the range 0.1–1.0%, depending on temperature and type of salami. Display at 20 °C increased the rate of O_2 depletion compared to 4 °C. To minimize discoloration, sliced and packaged salami should be stored in darkness at approximately 20 °C until the level of residual O_2 is reduced below a critical limit.

1. Introduction

Dry-cured fermented sausages of salami type are widely produced in Europe and other parts of the world. Salami usually contains pork and occasionally other meats, as well as pork fat, sodium chloride, curing agents like nitrite and nitrate, reducing agents like ascorbic acid and ascorbate, spices, carbohydrates and starter cultures (Toldrá, 2002). The process of fermentation, ripening and drying of the sausages results in a weight loss of >30% (Cevoli et al., 2014). The red to pink colour of salami is produced by nitric monoxide binding to the muscle pigment myoglobin, forming nitrosylmyoglobin, and is stabilized by reduction of the pH in the sausage (Møller & Skibsted, 2002). Sliced, packaged salami is prone to discoloration. Discolored salami and other meat products are contributing to undesirable food waste and lower commercial value at retail.

The discoloration of sliced, packaged salami is usually caused by the combination of residual O_2 in the packages and light exposure at display. Photooxidation of nitrosylmyoglobin comes from harmful light both in the ultraviolet and visible areas (Møller & Skibsted, 2002). Sliced, dry-cured Milano-type sausages were packaged in vacuum or 100% N_2 and exposed to light and temperatures typical for retail display for 60 days (Zanardi, Dorigoni, Badiani, & Chizzolini, 2002). The vacuum packaged sausages were less red than those in N_2 at the end of display, probably due to higher residual O_2 levels in the vacuum packages, but specific O_2 concentrations were not established. Furthermore, Spanish dry fermented sausages of Salchichón type were slightly less red in vacuum than 20% CO_2/80% N_2, but only by a 0.5 a* redness value (Rubio, Martínez, García-Cachán, Rovira, & Jaime, 2008). It seems like the level of residual O_2 in the headspace of the packages was not clarified.

The O_2 level in the headspace of the packages is a combination of several factors: residual O_2 level at time of packaging influenced by packaging machinery and operation, O_2 barrier properties of the packaging materials and oxygen consumption due to microbiological growth (Møller et al., 2003). The O_2 barrier property of the packaging film is crucial for the access of O_2 to the product. Sliced, vacuum packaged salami was analyzed for colour changes in films with O_2 transmission rates of 1, 11, 30, 72 and 90 ml/m^2/24 h at 23 °C and 0% RH, respectively (Yen, Brown, Dick, & Acton, 1988). Films with 30 ml or higher O_2 transmission rates resulted in less redness and more discoloration at light display, and the discoloration increased with longer light display, up to 8 weeks. In this study, no change in redness occurred with any of these films under dark storage. The level of residual O_2 in the headspace of salami packaged in modified atmospheres is reduced due to O_2 consumption by added and inherent bacteria in the product, mainly lactic acid bacteria. A study of O_2 levels of sliced, dry-cured sausages during storage in N_2 showed that the reduction of detrimental O_2 was faster at 22 than 4 °C, with initial O_2 concentrations of 8–14% over 120 days storage (Scetar, Kovacic, Kurek, & Galíc, 2013). In Norway, sliced salami is mostly packaged in modified atmospheres and displayed under light either in chill cabinets or at room temperatures. Cooked ham differs from dry cured sausages by having much lower total bacterial counts, at least early after packaging. Previously, the O_2 headspace levels for

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initiating discoloration of sliced, cooked ham with nitrite under light display have been set to 0.1–0.2% O_2, partly depending on the headspace volume (Larsen, Westad, Sørheim, & Nilsen, 2006; Møller, Jensen, Olsen, Skibsted, & Bertelsen, 2000). To our knowledge, such a critical level for residual O_2 in the headspace for modified atmosphere packaged sliced salami has not yet been established.

The purpose of this study was to determine the maximum levels of residual O_2 in the headspace of N_2 atmospheres to avoid discoloration of sliced Norwegian type salami displayed under light at 4 and 20 °C. The study comprised two types of commercial salami sausages, however, without investigating processing factors of the salamis in this study.

2. Materials and methods

2.1. Products for the experiment

Sausages from two batches of dry fermented salami were supplied by two Norwegian meat companies, and called A and B for this study. The recipes for both sausage types contain meat of pork and beef, pork fat, sodium chloride, spices, garlic, sodium nitrite, sodium ascorbate (A only), rosemary extract (B only), carbohydrates and starter cultures. The sausages were stuffed in 85 wide mm synthetic casings, and weighed approximately 4 kg each after drying. Salami A consisted of 35% fat, 21% protein, 6% sodium chloride and 38% water. Salami B consisted of 35% fat, 18% protein, 5% sodium chloride and 41% water. The sausages A and B were sliced and packaged approximately 1 and 2 months after completed production, respectively.

2.2. Experimental set-up

In a first small experiment, packages with sliced salami were injected with air to obtain 1.0% O_2 in the headspace, and then the reduction of residual O_2 was followed for 7 days. The experiment included salami sausages A and B, and was performed under light display and in darkness, both at 4 and 20 °C, amounting to 2 sausage types × 2 display conditions × 2 temperatures × 4 replicates = 32 samples in total.

The second main experiment was a full factorial setup of the experimental factors, including type of salami (A and B), O_2 level (0, 0.10, 0.25, 0.40, 0.75, 1.0 and 20.95%) and temperature (4 and 20 °C). The concentrations of O_2 were chosen to mimic common levels at packaging (0.1–0.4%), elevated levels by malfunction of packaging (0.75 and 1.0%) and complete leakage (21%). All samples were subjected to light, and in addition, the 1% samples were stored in darkness for comparison. Three replicates were made of each experimental condition, amounting to 32 × 3 = 96 samples in total. Instrumental colour analysis was performed on all samples at day 1, 2, 4 and 7, and visual colour evaluation on one of the replicates at days 1, 2 and 4.

2.3. Slicing, packaging and light display

All these operations took place at the Nofima pilot plant. The sausages were sliced on a Bizerba VS12D machine (Bizerba, Balingen, Germany). The slices were 1.0 mm thick and weighed ca. 5 g. Two stacks with 14 slices each were used for one package, yielding ca. 140 g of sausage per package. The holding time for the stacks from slicing to the completed packaging was approximately 45 min at 18–20 °C.

Packaging was performed on a Multivac R145 thermoforming machine (Multivac, Wolfertschwenden, Germany). The black base film was of type Multipet 450 and the transparent top film of type Biaxer 65 XX HFP AFM (both Wipak, Nastola Finland) with O_2 transmission rates of 10 and 5 ml/m^2·day, 1 atm at 23 °C and 50% RH, respectively. The base film was formed into trays 21.5 cm long, 10.8 cm wide and 1.8 cm high. The slices were packaged in 100% N_2 (AGA, Oslo, Norway). The gas to product or sausage volume ratio (G:P) was approximately 2 to 1. After packaging, the levels of residual O_2 in headspaces were 0.1–0.4%. All packages with salami slices were first stored in darkness at 4 °C for 14 days to allow for complete removal of residual O_2 from the headspaces. To obtain packages with elevated levels of O_2 in the headspace, variable volumes of air were then injected into the packages using syringes with needles through self-sealing septas of type 644,209 (Dansensor, Ringsted, Denmark). Packages with air or 20.95% O_2 were punctured once with a needle. The light display trial started within one hour after supply of air. Storage time for sufficient removal of O_2 and level of injection of air for suitable O_2 concentrations were established through pre-trials.

The light display was standardised to approximately 930 lx continuously at the surface of the salami slices for up to 7 days, both at 4 and 20 °C. The fluorescent lamps at 4 °C were Natura de luxe L36W/76 (Osram, Munich, Germany) and at 20 °C Auralight T5 Supreme HO 49W/830 (Auralight International AB, Karlskrona, Sweden) both typically used for illumination of meat products in display cabinets and from ceilings in food shops in Norway. The light intensity simulating retail conditions was obtained by adjusting the distance between the light sources and the salami surfaces. The packages under light display were rotated on days 1, 3 and 5 to expose the different samples to nearly uniform levels of light.

2.4. Analyses

The concentration of O_2 in the headspace of the packages was obtained with a Dansensor Checkmate 3 instrument (Dansensor, Ringsted, Denmark) by the use of a small vacuum pump and a needle inserted through self-sealing septas (Dansensor), withdrawing 7 ml of gas. All packages were analyzed at days 0, 4 and 7 of display, while spot tests were performed on days 1 and 2.

Instrumental values (L* - lightness, a* - redness and b* - yellowness) were obtained with a Minolta Chroma Meter CR-400 (Konica Minolta, Inc., Tokyo, Japan) with a 8 mm viewing port, 2° viewer angle and illuminant D_{65}. The instrument was calibrated against a white tile (L* = 97.16, a* = 0.25 and b* = 2.09). The samples were measured in intact packages at the product surface through the transparent film. The instrumental colour measurements were performed in four replicates on all samples.

Visual colour evaluation was performed by a 6 member trained panel. The colour of the salami slice surfaces was assessed on a scale of 1 = very red, 2 = slightly red, 3 = slightly brown, 4 = moderately brown and 5 = very brown, adapted from AMSA (2012). Additional standard samples exhibiting scores of 1 and 5 were used at all sampling days as examples for the assessors. During the evaluation, the samples were randomly displayed under PlusLux 3000 warm white light (Thorn, Durham, England) with a light intensity of 1600 lx at the salami surfaces.

Fading of the sausages was analyzed on a Foss XDS Opti Probe Analyzer Reflection and Immersion instrument (Foss NIRSystems Inc., Laurel, Maryland, USA). Spectra of 400–700 nm with 10 nm intervals were measured in samples from one replicate at day 4 of display directly through the top film of intact packages. The ratio 650/570 nm expressed the degree of fading of cured meat products with scale ca. 1.1 = no cured colour, ca. 1.6 = moderate fading, 1.7–2.0 = noticeable cured colour and 2.2–2.6 = excellent cured colour (AMSA, 2012).

pH was measured directly in the sausages with an Ingold Xerolyt electrode (Mettler-Toledo, Greifensee, Switzerland). Water activity of the sausages was analyzed at 25 °C with an AquaLab CX-2 instrument (Decagon Devices Inc., Pullman, Washington, USA).

2.5. Statistics

The colour parameters were evaluated by a fixed-effects ANOVA model with main effects type of salami, temperature, O_2 level and days of storage. All two-factor interactions were also included in the ANOVA model. The samples with 21% O_2 and the samples stored in darkness were kept out of the ANOVA analysis, but included in the