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Effect of retail display illumination and headspace oxygen concentration on cured boiled sausages

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ABSTRACT

The objective of this study was to investigate the influence of various commercial lamps and residual oxygen on discoloration and oxidation of cured boiled sausage. The wavelength dependence of different spectral bands on sausage color and oxygen absorption was investigated. A model packaging system, simulating a gastight package was used to compare the influence of fluorescent tubes, metal halide lamps, color optimized fluorescent tubes and LEDs. Sausages exposed to daylight fluorescent tubes showed significantly ($p < 0.005$) higher rates of oxygen absorption and discoloration in comparison to metal halide lamps and color optimized fluorescent tubes for meat products after 24 h of storage time at 6 ± 1 °C. To investigate the effect of light and residual oxygen in the headspace of the packaging, oxygen concentrations of 0.0%, 0.5%, 1.0% and 2.0% were tested with daylight fluorescent tubes in regard of oxygen absorption and discoloration of the sausages. Higher residual oxygen concentrations showed higher discoloration and also higher rates of oxygen absorption of the sausage. Low initial oxygen contents in the headspace of packaged sausage in conjunction with optimized illumination can prolong the shelf life of cured sausages in retail shelves.

1. Introduction

Color appearance of sausages is the most important attribute for buying decision in retail stores (Eyiler & Oztan, 2011). The consumers use the color of meat and meat products as an indicator of freshness (Haile, Smet, Claeys, & Vossen, 2011; Nicolalde, Stetzer, Tucker, McKeith, & Brewer, 2006). Therefore, the meat and meat products in retail shelves are mainly offered in transparent packaging (Gibis & Rieblinger, 2011; McMillin, 2008). Residual oxygen in conjunction with the cabinet display light causes discoloration of the packed products (Andersen, Bertelsen, Boegh-Soerensen, Shek, & Skibsted, 1988). Economic losses of about 1 billion US$ are reported by the discoloration of fresh beef due to price reduced and discarded meat (Smith, Belk, Sofos, Tatum, & Williams, 2000).

Food packaging serves to protect products against deteriorative effects. In recent years the demand for packaged meat products increased as well as the application of modified atmosphere packaging (MAP) to meat products and sliced cured boiled sausages. The main reason of MAP is to prolong the shelf life of perishable foods (McMillin, 2008). Two forms of MAP can be distinguished. The atmosphere inside a given volume can either be removed completely, denoted by vacuum packaging, or be replaced by a defined mixture of selected gases (Church & Parsons, 1995; McMillin, 2008). Two gases are generally used for cured products. CO_2 effectively inhibits the growth of many microorganisms. Nitrogen is used as a filler gas to replace oxygen. For cured products a modified

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atmosphere of 80% nitrogen and 20% carbon dioxide is recommended (Church & Parsons, 1995). Despite the application of modified atmosphere, there is often a small amount of residual oxygen (up to 2%) present in the package. This little amount of oxygen can lead to color fading by oxidation of the color pigment nitrosomyoglobin which is formed from myoglobin (Gibis & Rieblinger, 2011).

In meat myoglobin, the red iron-containing pigment which is responsible for meat color mainly exists in different conformations. The denaturated nitrosomyoglobin (dMbNO) is formed when muscle myoglobin reacts with nitrite to nitrosomyoglobin and is heated up to 65 °C until the pigment is converted into the denaturated form (Fox, 1966; Andersen et al., 1988). The denaturated nitrosomyoglobin causes the characteristic pink color of cured boiled sausages and is also named nitrosylmyochrome (Andersen & Skibsted, 1992), nitrosylmyochromogen (Bak et al., 2013) or nitrosohemochromogen (Sun, Zhou, Xu, & Peng, 2009). The exposure of dMbNO to light and oxygen promotes oxidation to metmyoglobin (Møller, Jensen, Olsen, Skibsted, & Bertelsen, 2000). Metmyoglobin (MMb) appears as brownish color on the meat surface (Faustman & Cassens, 1990; Mancini & Hunt, 2005).

In conclusion the discolouration of cured meat products is predominantly caused by light and oxygen (Møller, Bertelsen, & Skibsted, 2002; Haile et al., 2011). The redness of cured meat products can be measured as a^*value. A decrease in a^*value can be explained by the chemical reaction of the light induced oxidation of the color pigment and is described by Andersen and Skibsted (1992) as:

$$\mathrm{MbNO} + h\upsilon \rightarrow \mathrm{MbNO}^* \quad \text{(i)}$$

$$\mathrm{MbNO}^* + {}^3\mathrm{O}_2 \rightarrow \mathrm{MMb} + \text{other products} \quad \text{(ii)}$$

The nitrosylmyoglobin (MbNO) is a light sensitive substance functioning as a photosensitizer like dMnNO and is promoted to an excited state upon absorption of light. The activated state of MbNO* reacts with triplet oxygen ($^3O_2$) and forms metmyoglobin (MMb) and other products. Metmyoglobin formation causes the gray brown color of illuminated cured sausages and therefore the decrease in a^*value (Andersen & Skibsted, 1992).

Møller et al. (2000) found that 0.5% oxygen in the headspace of a modified atmosphere packaging leads to a significant light induced discoloration of cured cooked ham when illuminated with fluorescent tubes in a chill cabinet with 1000 lx compared to products stored in the dark. The consumers' purchase decision is influenced by the light source; the desirability of salami illuminated with fluorescent (FL), incandescent (IC) and metal halide lamps (MH) was significantly higher with incandescent light (Barbut, 2004). Different light sources have several spectral properties. IC and MH have a high emission in the infrared range and produce heat which increases the surface temperature of meat and meat products and reduce the shelf life (Calkins, Goll, & Mandigo, 1986). FL has a higher emission in the UV-A range. UV-light reduced the retail shelf life of beef steaks significantly compared to steaks stored in the dark or with absence of UV radiation (Djenane, Sánchez-Escalante, Beltrán, & Roncalés, 2001). Barbut (2001) found that four of five retail stores use cool white fluorescent lamps for meat illumination because of cost saving. The product appearance was different because of a weak emission in the red range in comparison to daylight or incandescent light. Andersen et al. (1988) found that the color of sliced packaged ham displayed in chill cabinets was dependent on the combination of light in the visible range and oxygen in the headspace of the packaging. Unlike to fresh beef, cured (boiled) sausages showed no sensitivity to UV-light in case of discoloration (Djenane et al., 2001; Sáenz, Hernández, Beriain, & Lizaso, 2005). The discolouration or graying of cured boiled sausage depends on wavelength (Kampschmidt, 1955). Every lamp type has special spectral properties. Light sources vary widely and range from overhead fixtures to lights positioned inside the display case. Therefore, different illumination sources influence not only the product appearance, but also the product quality during storage in retail stores.

In the first trial of this study, the influence of daylight fluorescent tubes, color optimized fluorescent tubes for meat products, metal halide lamps and LEDs were investigated on color and oxidation of cured boiled sausages. These lamps represent commonly used lamps in retail stores for the illumination of meat counters and self-service shelfs (Barbut, 2001; Wieser, 2010). The tested parameters were oxygen absorption, color changes and rancidity (hexanal) of the sausages during storage. A standardized oxygen concentration in the headspace was used for analyses. In the second trial, the effect of different initial oxygen concentrations and daylight fluorescent tube light was investigated on discoloration and oxygen absorption of cured boiled sausage.

2. Material and methods

2.1. Sample preparation

"Lyoner" type sausages were manufactured at Fraunhofer IVV in Freising, Germany with a standard recipe consisting of 3.5 kg lean pork meat category SII (lean pork meat without tendons with a maximum of 5% visible fat), 3.0 kg fat (50% jowls, 50% neck fat), 1.35 kg water (ice), 7.5 g ascorbic acid (Wiberg, Germany), 22.5 g diphosphate (Wiberg, Germany), 150 g sodium nitrite 0.65% (esco, Germany), 22.5 g sugar (Wiberg, Germany), 18.75 g pepper (Wiberg, Germany), 7.5 g ginger (Wiberg, Germany), 7.5 g cardamom (Wiberg, Germany) and 7.5 g nutmeg (Wiberg, Germany). Seven pigs were slaughtered in slaughterhouse Šentjur, Slovenia. The carcasses of the pigs were deboned and deep-frozen (−18 °C) directly after refrigeration. Two weeks after slaughtering the meat was defrosted for 24 h at 2 °C for sausage production. After grinding the meat through a plate with 6 mm openings, the lean meat was added to the chopping bowl (Typ 30 L 5000 Express, KILIA Fleischerei- u. Spezialmaschinenfabrik, Germany) and chopped for several minutes with sodium nitrite, diphosphate and one-third of the crushed ice until a temperature of 4 °C was reached. This was followed by the addition of fat and the spices with 0.45 kg crushed ice. The sausage meat was chopped up to 8 °C, then the bowl chopper was scraped out and the rest of the ice was added. The lid of