FACTORS CONTRIBUTING TO FADING AND DISCOLORATION OF SLICED, PACKAGED SALAMI UNDER ILLUMINATION

Oddvin Sørheim[1*], Solveig Uglem[2], Per Lea[1], Ingrid Måge[1], Marit Kvalvåg Pettersen[1] and Hanne Larsen[1]

[1]Nofima AS, Osloveien 1, NO-1431 Ås, Norway

[2] Grilstad AS, Ranheimsvegen 129B, NO-7053 Ranheim, Norway

[*]Corresponding author email: oddvin.sorheim@nofima.no

Abstract - Sliced salami packaged in modified atmospheres is prone to discoloration caused by the combination of residual O_2 in the headspace and light exposure at display. In this study, factors contributing to discoloration of salami were examined. The consumption of detrimental residual O_2 was faster at 20 than 4 °C. Light-induced discoloration increased with increasing levels of initial residual O_2 in the packages, and was higher at 4 than 20 °C. Salami in packages without O_2 present had a slight fading under light at 20 °C. To avoid discoloration of sliced, packaged salami, the packages should be stored in darkness until nearly all residual O_2 is consumed by the product. Thereafter, the product can safely be displayed under light without risking discoloration that would cause consumer rejection and food waste.

Key Words – colour, dry cured sausage, light exposure, residual oxygen.

I. INTRODUCTION

Fermented and dried salami sausages are available in many parts of the world with different processing and packaging. For sliced packaged salami, a red colour is regarded as one of the main criteria for purchase. Discoloration of the product can cause rejection by consumers, food waste and economical loss. Photooxidation of the pigment nitrosylmyoglobin is due to the combined effects of oxygen and light [1]. Modified atmosphere packaging (MAP) has become common for sliced salami, usually with 100 % N_2 or N_2 with small fractions of CO_2. Crucial for stabilizing colour of cold cuts in MAP is keeping residual O_2 in the headspace at a low level [2] and using packaging materials with high O_2 barrier properties [3].

In Norway, shelf stable raw fermented salami with a water activity below 0.90 is sold at room temperature, or in chilled cabinets. The display of dry cured sausages at various temperatures can affect colour and other quality parameters of the products.

The aim of this study was two-fold: to evaluate the effects of various levels of residual O_2 on the colour of sliced, packaged salami under light display, and elucidate possible non-O_2 related light effects on colour changes of the product.

II. MATERIALS AND METHODS

The study was designedh with two experiments using sliced, packaged salami, the first with different concentrations of residual O_2 and the second without O_2. The samples were displayed under fluorescent light at 4 and 20 °C.

Salami sausages from Grilstad (Ranheim, Norway) were used in the study. The sausages had a diameter of 75 mm and contained ca. 35 % fat.

The first packaging experiment was conducted in the pilot plant at Nofima. Sausages were sliced and packaged on a Multivac R145 thermoforming machine (Multivac, Wolfertschwenden, Germany). The base web and top film named Multipet 450 and Biaxer 65 XX (both Wipak, Nastola, Finland) had O_2 transmission rates (OTR) of 10 and 5 cm^3/m^2/day at 23 °C and 50 % RH. Gas to product ratio was ca. 2:1. The packages were initially stored for 14 days at 4 °C in darkness to allow for complete removal of residual O_2 from headspace by internal O_2 consumption by the product.

Shortly before illumination, various levels of air corresponding to 0.1 to 1.0 % O_2 were injected into the packages through septas. Packages with air were made by puncturing with a needle.

The second packaging experiment was performed at Grilstad with a thermoforming machine, using high barrier base web and top film with OTR`s below 5 cm^3/m^2/day at 23 °C and 50 % RH. These packages were stored in darkness, first at 10 ° C for 1.5 months, followed by 4 and 20 °C for another 4.5 months, before being exposed to light with no residual O_2 in the headspace.

The illumination for both packaging experiments was performed in the Nofima lab. The light intensity was ca. 1000 lux continuous at the salami surfaces at both display temperatures. At 4 °C, Natura de luxe L36W/76 (Osram, Munich, Germany) recommended for meat display illumination was used. At 20 °C, Auralight T5 Supreme HO 49W/830 (Auralight Int., Karlskrona, Sweden) common for ceilings of grocery stores was used. The light exposure lasted for 4 and 13 days for the first and second packaging experiments, respectively. 4-5 packages were used for each series and test conditions.

Analyses included measurement of residual O_2 in the headspace of packages by using a Checkmate 3 instrument (Dansensor, Ringsted, Denmark). CIE a* redness values on the salami surfaces were analysed non-destructively through the top films 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} with 4 replicate measurements per sample.

Statistics was performed in MATLAB (R2014b, The Mathworks, Inc., Nattick, MA, USA). a* values were evaluated by a fixed-effects ANOVA model with the main effects temperature, O_2 level and days of storage.

III. RESULTS AND DISCUSSION

In the first experiment, the rate of O_2 consumption was studied with a fixed initial O_2 headspace concentration of 1.0 %, and packages were displayed at 4 and 20 °C for 4 days under light (Fig. 1). The data show that the O_2 consumption was dependent on temperature, with much faster decline in O_2 concentrations at 20 compared to 4 °C. The bacteriological activity and requirement of O_2 from starter cultures in the sausages were probably higher at 20 °C. In agreement with our study, the O_2 consumption of dry cured sausages under long term dark storage was higher at 22 than 4 °C [4].

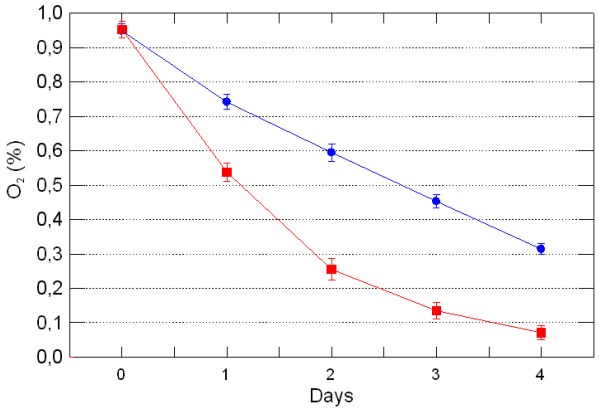

Figure 1. Reduction of residual O_2 in the headspace of illuminated packages with sliced salami initially filled with 99 % N_2 and 1 % O_2. Symbols: ● at 4 °C and ■ at 20 °C.

The effect of different initial O_2 concentrations between 0.1 and 1.0 % on a* redness values after 4 days of light display is demonstrated in Fig. 2. a* values declined with increasing level of residual O_2. Samples in air, simulating a full leakage, had much lower a* values. With exception of samples in 0.25 and 21 % O_2, the redness was temperature dependent, with significantly ($p < 0.05$) higher a* values at 20 than 4 °C, due to the faster removal of residual O_2 at this high temperature (Fig. 1). An additional control with 1.0 % O_2 was stored in darkness for 4 days, and had a* values of ca. 16 both at 4 and 20 °C, not different ($p > 0.05$) from illuminated samples in 0 % O_2.

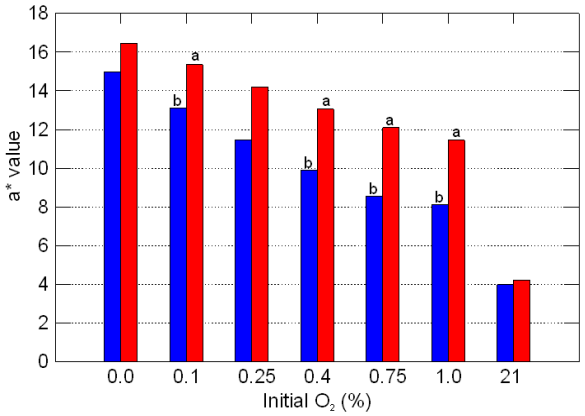

Figure 2. a* values of sliced, packaged salami with 0 – 21 % initial O_2 and displayed under light at 4 and 20 ° C for 4 days. Symbols: ■ at 4 °C (left bars) and ■ at 20 °C (right bars). Bars with different letters are significantly different ($p < 0.05$).

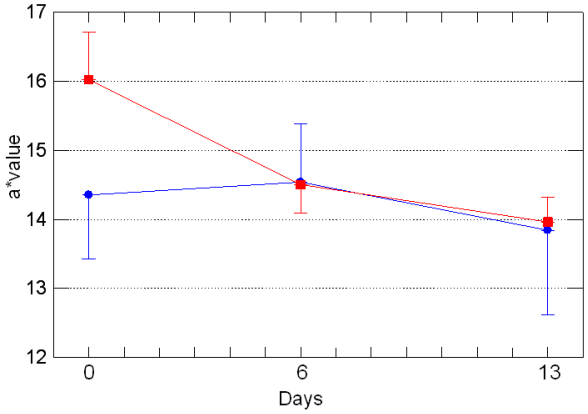

Figure 3. a* values of sliced, packaged salami without residual O_2 and displayed under light at 4 and 20 °C for 13 days. Symbols: ● at 4 °C and ■ at 20 °C.

In the second experiment, packages with sliced salami without residual O_2 in the headspace were illuminated for 13 days, and a* values were recorded (Fig. 3). Samples at 4 °C did not differ between 0, 6 and 13 days display ($p > 0.05$). However, samples at 20 °C started at higher a* values and redness than at 4 °C ($p < 0.05$), and declined by 1.5 – 2 a* values to days 6 and 13 ($p < 0.05$). This fading or slight loss of redness is not likely explained by photooxidation processes, but could be due to changes in surfaces properties like reflectance and interaction with fat and the melting point of this substance. The fading phenomena is of a much lower magnitude than the photooxidation by residual O_2 (Fig. 2), and is not likely to cause consumer rejection. Still, the data suggest that a slight fading of salami can take place even without measureable O_2 present in the headspace.

The results of this study demonstrates that too high levels of residual O_2 in packages of sliced packaged salami at the start of illumination can cause discoloration, which increased with increasing levels of O_2. These findings are in agreement with results of cooked cured ham, where 0.15 % residual O_2 was set as maximum acceptable level [2]. Display at an elevated temperature, like 20 °C, reduced the extent of discoloration in the present salami, because of the higher consumption of detrimental residual O_2 at this temperature. However, other undesirable quality changes like fat oxidations and incipient fat melting can be a concern at higher temperatures.

IV. CONCLUSION

Sliced, packaged salami should be stored in darkness until all or nearly all residual O_2 in the headspace is consumed by the product. Light-induced discoloration was less severe at 20 than 4 °C, because internal O_2 consumption by the product was faster at the highest temperature.

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