CRITICAL FACTORS FOR THE COLOUR OF GROUND BEEF PACKAGED IN LOW OXYGEN ATMOSPHERES.

O. Sørheim[*1], F. Westad[1,2], H. Larsen[1], and O. Alvseike[3]

1 *Matforsk AS – Norwegian Food Research Institute, Osloveien 1, NO-1430 Ås, Norway*
2 *M-Analyse, Arildsvingen 12, NO-0491 Oslo, Norway*
3 *Animalia – Norwegian Meat Research Centre, P.O. Box 396 Økern, NO-0513, Oslo, Norway*

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Introduction
Raw ground beef is particularly vulnerable to myoglobin oxidation and discoloration, because of the physical disruption of the meat structure and incorporation of air during grinding (Madhavi and Carpenter, 1993). Ground beef with a bright red colour is produced in the presence of oxygen (O_2) or carbon monoxide (CO). In Norway, the use of low CO packaging for ground beef was discontinued in 2004, causing the industry to shift to atmospheres of carbon dioxide (CO_2)/nitrogen (N_2). Residual O_2 in the head space of these atmospheres can discolour the meat. In beef, oxidized metmyoglobin with a brown/gray colour is formed at O_2 concentrations as low as 0.1 % and at a maximum of appr. 1.5 % O_2 (Ledward, 1971; O`Keeffe and Hood, 1980). The practice of using partly frozen/thawed meat and adding salt (sodium chloride) to Norwegian ground beef may both contribute to discoloration (Trout, 1990).

The aim of the present experiment was to elucidate the effects of freezing of raw materials, addition of NaCl and low O_2 packaging on the colour of ground beef.

Materials and Methods
Sixty kg of beef trimmings with 14 % fat and pH 5.65 were purchased 7 days after slaughter. Half of the meat was frozen at -20 ˚C for 3 weeks, and then thawed at 3˚C. The following 4 series were produced: fresh meat without NaCl and water, fresh meat with 1 % NaCl and 5 % water, frozen meat without NaCl and water, and frozen meat with 1 % NaCl and 5 % water. The meat was ground twice through plates with 8 and 4 mm openings. A brine was blended manually into the meat before the last grinding. Portions of 400 g of ground beef was placed on trays and packaged in ethylenevinylalcohol bags (Nordfilm B 206, Nordpak OY, Valkeakoski, Finland) with an O_2 transmission rate of 3 cm^3/m^2*24h at 23 ˚C and 0 % RH. The bags were flushed with 55 % CO_2/ 45 % N_2 to a gas:meat ratio of 2.5:1. In each series, 20 packages were produced with O_2 concentrations of 0.1 – 1.5 % by inserting air with a syringe through self-adhesing rubber septas. More samples were prepared in the lower than the upper O_2 range. The meat was stored in darkness at 4 ˚C for 9 days.

O_2 was analysed with a Toray LC 700-F zirconium cell instrument (Toray Engineering, Osaka, Japan) calibrated against a 0.10 % O_2 standard gas. Gas volumes of 10 cm^3 were sampled with a syringe. CIE a* (redness) values were measured with a Minolta Chroma Meter CR-300 (Minolta Camera Co., Osaka, Japan) through the packaging film in 4 replicates per sample. Both O_2 and colour analyses were performed on all samples at days 1, 2, 3, 6 and 9 of storage. Analysis of variance (ANOVA) was employed to analyse O_2 and a* data.

Results and Discussion
As shown in Figure 1, the decline in O_2 concentrations was fastest in the fresh/non-salted series, passing 0.1 % before 6 days of storage. The O_2 level of the fresh/non-salted series was lower than the other 3 series between 1 and 9 days ($p < 0.05$). The three series of frozen/non-salted, fresh/salted and frozen/salted meat were slow in O_2 depletion, ending at 0.15 – 0.25 % at 9 days. As illustrated in figure 2, ground beef of the fresh/non-salted series increased considerably in a* (redness) values between 1 and 6 days of storage. a* values of meat of the fresh/non-salted series was higher than the other three series between 3 and 9 days ($p < 0.05$). The high a* value of frozen/salted meat at day 1 was probably caused by presence of fractions of transient oxymyoglobin.

The present results demonstrate that a rapid decline in residual O_2 levels corresponded well with an increase in a* values, presumably through a gradual reduction of initial metmyoglobin to deoxymyoglobin (Eie et al., (2007). The fastest O_2 depletion was noted for fresh/non-salted, followed by frozen/non-salted, fresh/salted

and frozen/salted series, with a* values in the opposite order. The use of frozen/thawed meat and addition of NaCl both negatively affected O_2 depletion and metmyoglobin reduction. In agreement with our results, Trout

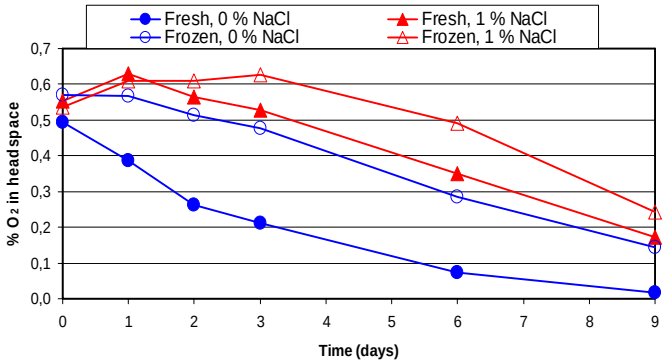

Figure 1. Mean concentrations (n=20) of residual O_2 in the head space of packages of 4 types of ground beef stored in a CO_2/N_2 atmosphere at 4 ˚C for 9 days.

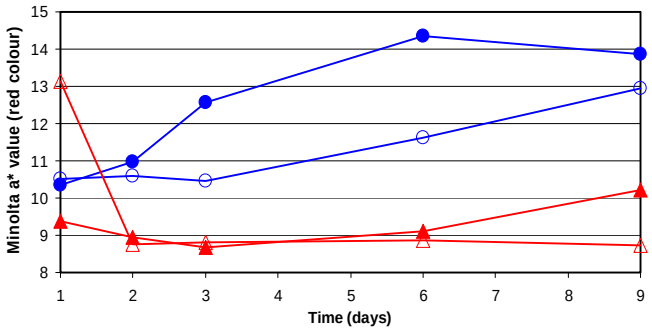

Figure 2. Mean a* (redness) values (n=20) of 4 types of ground beef stored in a CO_2/N_2 atmosphere with residual O_2 at 4 ˚C for 9 days. For description of ground beef types and symbols; see figure 1.

(1990) found that 0.5 – 3.0 % NaCl increased metmyoglobin formation in ground beef. By evaluating individual samples, the general requirement for obtaining a predominantly purple colour of deoxymyoglobin for ground beef was to keep the meat in CO_2/N_2 atmospheres with less than 0.1 % O_2 for more than 2 days. The mentioned requirement was all valid for fresh, frozen/thawed, non-salted and salted ground beef.

Conclusions

The use of frozen/thawed meat and addition of salt were both detrimental to the colour of ground beef. Ground beef should be stored in CO_2/N_2 atmospheres with less than 0.1 % O_2 for a minimum of 2 days for achieving a purple colour.

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