NEW ALTERNATIVES FOR INCREASING COLOR STABILITY IN FROZEN BEEF

LANARI M.C., SCHAEFER D.M., CASSENS R.G. and SCHELLER K.K.

Dept. of Meat & Animal Sci., Univ. of Wisconsin-Madison, USA.

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SUMMARY

We analyzed a) the influence of blooming time (1, 6, 48 h) and atmosphere (air or 100% O_2) prior to freezing on color stability of longissimus lumborum (LL) obtained from control and vitamin E supplemented steers and b) the effect of different levels of vitamin E (0, 620, 700 and 2100 IU/head/day) on color stability of frozen LL. Samples were stored at -20°C with and without illumination. Supplementation coupled with blooming for 6 or 48 h in 100% oxygen provided the highest color stability in both dark and illuminated storage. Color display lives for supplemented LL bloomed for 6 and 48 h in O_2 were 182 and 212 days for dark storage and 21 and 73 days for illuminated display. Tissue content of vitamin E and color stability of LL bloomed 48 h in air increased with supplementation level. Color display lives of control and supplemented (620, 700 and 2100 IU/head/day) LL stored in the dark were: 0, 117, 146 and 179 days respectively. For the same levels of supplementation, frozen LL stored under illumination remained acceptable for 0, 32, 37 and 99 days.

Introduction

Recent reports showed that dietary supplementation of Holstein steers with high levels of vitamin E increased lipid and color stability of frozen longissimus lumborum (LL) during dark storage or illuminated display (Lanari et al., 1993; 1994). One major disadvantage to this technique is that the meat was exposed to air for 48 h prior to freezing in order to bloom (oxygenate).

No information is available about the relationship between color stability of frozen beef and α-tocopherol content in the muscle; thus it will be of great importance to determine the dose which will produce the optimum effect .

This study was designed to analyze: a) the relationship between color stability of control and supplemented LL and blooming conditions (duration and atmosphere) prior to freezing and b) the effect of different levels of vitamin E on the color stability of frozen LL obtained from control and supplemented steers.

Materials and Methods

Meat samples were obtained from the LL muscle of Holstein steers fed a 90% high-moisture corn-plus-supplement and 10% corn silage diet which contained 0.1 ppm selenium. Three animals per treatment received 0 (control), 620, 700 or 2100 IU/head/day of α-tocopheryl acetate (vitamin E, Hoffmann-La Roche, Inc., Nutley, NJ) per head daily for 105-126 days prior to slaughter. Loins were removed at 24 h post mortem, vacuum-packaged and aged for 14 days at 4°C.

To study the relationship between color stability and blooming conditions, samples from control and supplemented steers (620 IU/head/day) were cut, wrapped in a highly oxygen permeable film (fresh meat PVC film) and exposed to air or 100% O_2 for 1, 6 or 48 h at 4°C to allow blooming. After blooming, beef samples were skin-packaged in polyethylene, frozen to -20°C and stored at the same temperature in the dark or under constant illumination using Cool White fluorescent lights with an intensity of 1614 lux.

The effect of vitamin E concentration on color was evaluated using four levels of dietary intake of vitamin E, 0 (control), 620, 700 and 2100 IU/head/day. For this experiment, meat packaged in PVC, was exposed to air for 48 h. After blooming, samples were processed as previously described.
The concentration of vitamin E in the tissue was determined by the method of Arnold et al. (1993).

Color was measured for triplicate samples with a Minolta Chroma Meter CR-200. Meat color was expressed by its saturation index (SI) and computed as:

$$SI = (a^{*2} + b^{*2})^{0.5}$$

Data were analyzed as a split-plot design. SI variations over time were fitted by a regression model. Parameters were estimated by nonlinear regression analysis using DUD and Gauss-Newton minimization methods.

Results and Discussion

Accumulation of α-tocopherol in the muscle increased with supplementation level. α-tocopherol concentrations ± SD, in µg/g of fresh meat, for control and supplemented LL were 0.66 ± 0.17 (control); 2.25 ± 0.15 (620 IU); 2.93 ± 0.25 (700 IU) and 5.25 ± 0.64 (2100 IU).

Relationship between color stability and pre-freezing blooming conditions

Results from the main effects of the statistical analysis showed that SI of control LL was considerably lower ($P<0.001$) than for supplemented LL indicating a greater degree of discoloration. Use of an O_2 atmosphere during blooming improved SI ($P<0.001$) in both control and supplemented LL. Light had a strong detrimental effect ($P<0.001$) on the surface color of control and supplemented meat. Interaction of vitamin E effect with blooming time and atmosphere was highly significant ($P<0.001$). For control meat bloomed in air or O_2 and stored in the dark and control LL bloomed in O_2 and kept under illumination (data not shown), an increase of the blooming period from 1 to 6 h enhanced SI ($P<0.001$). When control LL was bloomed 48 h before freezing and treated as before, SI was lower ($P<0.0001$) than for meat bloomed for 1 h (data not shown). These results can be explained by considering that an increase of the blooming time has two opposite effects on color: a) an enhancement of color stability due to the production of a thicker layer of oxymyoglobin and b) a loss in reducing capacity of the tissue with blooming time.

Variations of SI with time are shown in Fig. 1. For supplemented LL bloomed in air and stored in the dark the ranking of color stability was the same as for control LL treated in a similar way. For the rest of the experimental conditions, color stability increased with blooming time. The highest color stability was achieved blooming supplemented LL in O_2 for 48 h.
Experimental data were satisfactorily fitted by:

$$Y = Y_0 * e^{(-k*t)} + Y_eq$$

Y represents SI at time t, Y_0 and Y_eq the initial and equilibrium values of Y, respectively, and k is the rate constant ($days^{-1}$). If the discoloration rate is slow enough that the equilibrium conditions are not attained, $Y_{eq} = 0$.

Considering a SI value of 16 as the limit of acceptability for frozen beef (Lanari et al., 1993), it was possible to calculate the display-life for each treatment combination (Table 1). Color display life ranges were determined for the storage times when the 95% confidence interval of the regression line included the SI value of 16. Results from control LL bloomed for 1 h and stored with or without illumination and supplemented meat exposed for the same period (1 h) and kept in the dark revealed no benefit for treating in O_2. However, for longer blooming times (6 or 48 h), O_2 effect was more marked in supplemented LL. Dietary supplementation with vitamin E coupled with a blooming period of 48 h in O_2 atmosphere prior to freezing provided the greatest extension in display life. If meat will be stored in the dark, the blooming period can be shorter; supplemented LL bloomed 1 h in air had a display life of 96 days. Supplemented LL with a pre-freezing exposure of 1 or 6 h in O_2 remained acceptable after 15 or 21 days of illuminated display. The light intensity used in these experiments (1614 lux) was considerably higher than the levels recommended for retail display (1076 lux or less) and can produce a decrease in color stability. Kropf (1982) showed that display temperatures of -26.1°C could overcome much of the effect of intense lighting. Andersen et al. (1989) reported a benefit in ground beef color stability by using polyethylene which contained a ultraviolet (UV) absorber. Therefore, decreasing the intensity to 1076 lux or less, the temperature to -26°C and wrapping the supplemented meat with polyethylene containing a UV barrier may provide a better color rendition and additional extension in color display life.

Color display life and α-tocopherol concentration

Statistical analysis indicated that SI increased ($P<0.001$) with the level of supplementation. Discoloration on supplemented samples was reduced and delayed ($P<0.001$). Color display life was calculated as described above. Relationship between color display life in the dark or under illumination, and α-tocopherol concentration in the tissue is shown in Fig. 2. To achieve a significant increase in color display life, the muscle should contain more than 1.2 μg/g of α-tocopherol. Supplementation effect on frozen LL stored in the dark was more noticeable for α-tocopherol contents between 0.7 and 4 μg/g. Beyond this level, the improvement in color display life was less marked. For LL kept under illumination, color display life was much lower compared to dark storage. The relationship between color display life and α-tocopherol concentration was quadratic ($R^2 = 0.93$) and linear ($R^2 = 0.98$) for dark and illuminated storage respectively. It is possible that at higher levels of α-tocopherol the increase in color display life for LL stored in the light will be small.

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Legends

Figure 1: Saturation index (SI) during dark or illuminated storage of supplemented LL after blooming in air or O_2 for 1 (o–o), 6 (▲—▲) or 48 h (□- -□). Solid and broken lines represent SI levels predicted by the regression model. From Lanari et al. (1994).

Figure 2:Color display life and vitamin E concentration for frozen LL stored in the dark (■-■) or under illumination (Δ-Δ). Solid lines represent color display life predicted by the regression model. From Liu et al (1994).