51st International Congress of Meat Science and Technology
August 7-12, 2005 – Baltimore, Maryland USA

COLOUR STABILITY AND OXIDATION IN RELATION TO TOCOPHEROL LEVELS IN RED DEER (CERVUS ELAPHUS) MEAT

Sampels, S.[1], Wiklund, E.[2], Pickova, J.[1] & Manley, T.[3]

[1]Swedish University of Agricultural Sciences, Department of Food Science, P.O. Box 7051, 750 07 Uppsala, Sweden, [2]University of Alaska Fairbanks, School of Natural Resources and Agricultural Sciences Reindeer Research Program, P.O. Box 757200, Fairbanks, Alaska 99775-7200, USA, [3]AgResearch Invermay, Puddle Alley, Private Bag 50034, Mosgiel, New Zealand.

Key Words: Red deer, meat, venison, colour stability, vitamin E, TBARS

Introduction

Meat colour is an important quality attribute in consumer purchase decisions for fresh meat. The browning of meat, which determines the colour display life, is caused by oxidation of myoglobin and oxymyoglobin to metmyoglobin (Ledward, 1992). The reaction rate of the pigment oxidation process depends upon numerous factors including fatty acid (FA) composition and antioxidant content of the meat.

Differences in FA composition can influence colour stability (Liu *et al.*, 1996) since more unsaturated FA are more prone to oxidation (Cosgrove *et al.*, 1987), and the relationship between higher content of polyunsaturated FA (PUFA) and poor colour stability have been discussed. Levels of antioxidants, such as vitamin E, influence the rate and intensity of the oxidation process (Gray *et al.*, 1996), and thus lipid and colour oxidation in meat and meat products can be decreased by dietary supplementation with antioxidants (Buckley *et al.*, 1995; Liu *et al.*, 1996).

Meat from grazing ruminants contains in general a higher proportion of PUFA and especially n-3 FA compared to meat from pellet fed animals. Grass and leaves have a high content of 18:3 n-3 (Elgersma *et al.*, 2003) whereas pellets are often based on grains rich in n-6 FA and oils instead of seeds which leads to hydrogenation of unsaturated FA in the rumen by microorganisms, if they are not naturally protected by cell walls as in grass and seeds, or by synthetic coatings (Wood & Enser, 1997). However, naturally growing plants in general contain sufficient amounts of antioxidant substances, which might even be sufficient to protect the meat against oxidation.

Objectives

The purpose of the present study was to investigate the influence of feeding regimen on colour stability, vitamin content and levels of oxidation products in red deer meat, and to investigate effects of long-term storage on these parameters.

Methodology

A total of 16 male red deer (age 1 year) were included in the study. Eight animals had grazed pasture and eight had been fed a pelleted feed mixture (Standard Deer Nuts, Reliance Stockfoods Ltd, Dunedin, New Zealand) for 10 weeks prior to slaughter. The animals were exposed to normal pre-slaughter handling, including yarding at the farm, a short transport and subsequent overnight lairage at a deer slaughter premises. At slaughter, all animals were stunned with a captive bolt. The slaughter procedure included electrical stimulation of the carcasses using a MIRINZ low voltage stimulator. Samples from the left side *M. longissimus dorsi* were taken at 30 min *post mortem* and frozen in liquid nitrogen (–196 °C). One day *post mortem*, *M. longissimus dorsi* from the left side were excised and cut in five pieces that were randomly allocated to sampling at 1 day *post mortem*, 1, 3, 6 or 12 weeks of refrigerated storage at –1.5 °C. Finally all samples were stored at –80 °C until further analyses.

Triplicate colour measurements were made on each freshly cut steak 2 hours after opening the vacuum bag, then twice daily using a Minolta Chroma meter (CR-300, Japan), as found appropriate for venison (Stevenson *et al.*, 1989). Days of acceptable colour (display life) were calculated as the time taken to reach an a^* value of 12 using linear interpolation between consecutive samples, as has been used previously for venison (Stevenson *et al.*, 1989; Wiklund *et al.*, 2001).

For the analysis of α-tocopherol, an HPLC method described by Högberg *et al.* (2002) was used. The HPLC column was a 4.0x250 mm RP-18 LiChroCART (Merck KGaA, Darmstadt, Germany). Mobile phase was pumped at a flow rate of 1.2 ml/min. Identification and quantification were done by external standards.

For the analysis of lipid oxidation products (thiobarbituric acid reactive substances (TBARS)) in red deer meat, a slightly modified method described by Miller (1998) was used to prepare samples before analysis by spectrophotometer at a wavelength of 530 nm. Quantification was made by using malondialdehyde (MDA) as an external standard, and a blank was measured to detect background absorbance. Amounts of TBARS were calculated as MDA equivalents by subtracting the blank from all standards and samples and by subtracting the sample blank from each sample.

Results & Discussion

Meat from the grazing deer had significantly longer colour display life at day 1 and after 1, 3 and 6 weeks of refrigerated storage (Fig. 1). TBARS increased during storage, but no significant differences between the treatment groups were found (Table 1). However, when the meat had been stored for 12 weeks, samples from the pellet fed animals had a tendency towards higher amounts of TBARS ($P = 0.067$) compared with samples from the grazing group (Table 1). Meat from grazing animals had a significantly higher content of α-tocopherol compared with meat from pellet fed red deer (Table 1). Storage did not decrease levels of α-tocopherol.

It is suggested that the difference in α-tocopherol content and not FA composition was mainly responsible for the shorter colour shelf life (faster browning) and for the slightly higher formation of TBARS in the meat from pellet fed deer during storage and display. Since oxidation prone n-3 FA (Cosgrove *et al.*, 1987) are present in high

proportions in pasture, opposite results for colour and lipid oxidation would be expected if meat FA composition was the main factor. It has been shown earlier that α-tocopherol has a protecting effect against pigment oxidation (Monahan *et al.*, 1994; Faustman *et al.*, 1998). Gatellier *et al.* (2004) and Gatellier *et al.* (2005) showed similar effects in beef, where grazing led to higher amounts of PUFA but also higher vitamin E content and better oxidation stability. In the same studies a slightly better colour stability of the meat from grazing animals was also found, indicating that negative effects of FA composition on colour stability can be reduced by efficient supplementation with antioxidants. Because significant differences in colour stability were already apparent in fresh red deer meat but differences in lipid oxidation were not, our results suggest that meat pigment oxidation occurs faster than lipid oxidation, and can reveal effects of diet and storage earlier than measurements of lipid oxidation. A similar conclusion was reached by Monahan *et al.* (1994), who found that myoglobin oxidation in pork stored at +4 ºC preceded lipid oxidation.

Conclusions

Meat from grazing red deer (with higher vitamin E content) had superior colour stability. Differences in vitamin E intake had larger influence on meat colour than did FA composition. Shelf life or colour stability was closely related to feeding regimen. Meat pigment oxidation occurs faster than lipid oxidation and thereby reveals effects of diet and storage earlier than measurements of lipid oxidation.

References

Buckley, D. J., Morrissey, P. A. & Gray, J. I. 1995. Influence of dietary vitamin E on the oxidative stability and quality of pig meat. J. Anim Sci., 73**,** 3122–3130.

Cosgrove, J. P., Church, D. F. & Pryor, W. A. 1987. The kinetics of the autoxidation of polyunsaturated fatty-acids. Lipids, 22 (5)**,** 299–304.

Elgersma, A., Ellen, G., van der Horst, H., Muuse, B. G., Boer, H. & Tamminga, S. 2003. Comparison of the fatty acid composition of fresh and ensiled perennial ryegrass (Lolium perenne L.), affected by cultivar and regrowth interval. Animal Feed Science and Technology, 108**,** 191–205.

Faustman, C., Chan, W. K. M., Schaefer, D. M. & Havens, A. 1998. Beef color update: The role for vitamin E. Journal of Animal Science, 76**,** 1019–26.

Gatellier, P., Mercier, Y., Juin, H. & Renerre, M. 2005. Effect of finishing mode (pasture- or mixed-diet) on lipid composition, colour stability and lipid oxidation in meat from Charolais cattle. Meat Science, 69**,** 175–186.

Gatellier, P., Mercier, Y. & Renerre, M. 2004. Effect of diet finishing mode (pasture or mixed diet) on antioxidant status of Charolais bovine meat. Meat Science, 67**,** 385–394.

Gray, J. I., Gomaa, E. A. & Buckley, D. J. 1996. Oxidative Quality and Shelf Life of Meats. Meat Science, 43**,** S111–S123.

Högberg, A., Pickova, J., Babol, J., Andersson, K. & Dutta, P. C. 2002. Muscle lipids, vitamins E and A, and lipid oxidation as affected by diet and RN genotype in female and castrated male Hampshire crossbreed pigs. Meat Science, 60**,** 411–420.

Ledward, D. 1992. In The chemistry of muscle based foods. (Eds, Johnson, D. E., Knight, M. K. and Ledward, D. A.) The royal society of chemistry, pp. 129–144.

Liu, Q., Scheller, K. K., Arp, S. C., Schaefer, D. M. & Williams, S. N. 1996. Titration of fresh meat color stability and malondialdehyde development with Holstein steers fed vitamin E-supplemented diets. Journal of Animal Science, 74**,** 117–126.

Miller, D. D. 1998. Food chemistry, A Laboratory Manual. Wiley Interscience, New York, USA.

Monahan, F. J., Asghar, A., Gray, J. I., Buckley, D. J. & Morrissey, A. 1994. Effect of oxidized dietary lipid and vitamin E on the colour stability of pork chops. Meat Science, 37**,** 205–15.

Stevenson, J. M., Seman, D. L., Weatherall, I. L. & Littlejohn, R. P. 1989. Evaluation of venison colour by an objective method using CIELAB values. Journal of Food Science, 54**,** 1661–1662.

Wiklund, E., Stevenson-Barry, J. M., Duncan, S. J. & Littlejohn, R. P. 2001. Electrical stimulation of red deer (Cervus elaphus) carcasses - effects on rate of pH-decline, meat tenderness, colour stability and water-holding capacity. Meat Science, 59**,** 211–220.

Wood, J. D. & Enser, M. 1997. Factors influencing fatty acids in meat and the role of antioxidants in improving meat quality. British Journal of Nutrition, 78**,** S49–S60.

Tables and Figures

Table 1. Content of TBARS and α-tocopherol (µg/g) in *M. longissimus* from red deer grazing or fed pellets. Fresh meat and meat after storage in vacuum packages at –1.5 ºC.

	Fresh meat		6 weeks storage		12 weeks storage	
	grazing	pellet fed	grazing	pellet fed	grazing	pellet fed
α-tocopherol	1.94[a]	0.39[b]	n.m.	n.m.	2.08[a]	0.34[b]
TBARS	0.22[a]	0.23[a]	0.45[b]	0.45[b]	0.43[b]	0.58[b]

Means with different superscripts within a row differ significantly (P<0.05)

n.m.= not measured

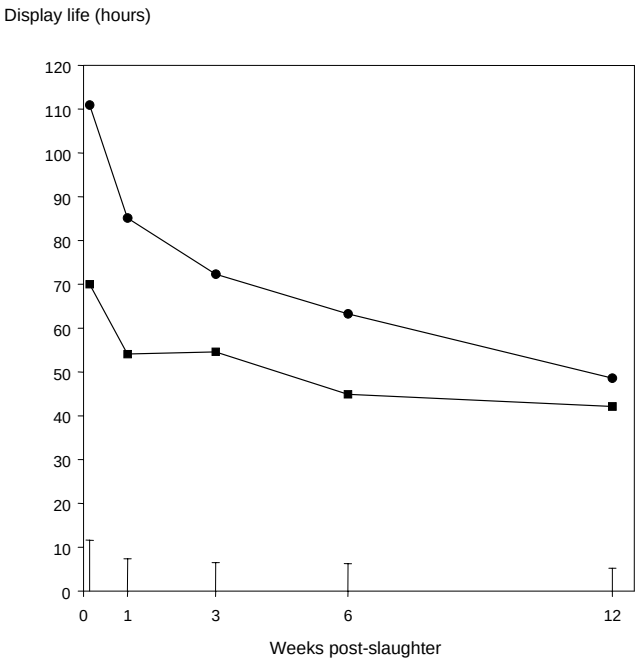

Figure 1. Mean display life (hours of Minolta a^* value ≥ 12) in *M. longissimus* from the red deer from two treatments (● pasture grazing and ■ pellet fed), measured at 1 day, 1, 3, 6 and 12 weeks of refrigerated storage (–1.5° C) in vacuum bags, with error bars indicating standard error of difference (S.E.D).