EFFECT OF MODIFIED ATMOSPHERE AND AGE AT SLAUGHTER ON THE LIPID OXIDATION AND THE INSTRUMENTAL COLOR OF LAMB MEAT

Renata E. F. Macedo[1*], Giovana M. Silva[2], Evelyn R. Stahlke[1], Luciane S. Rossa[2], Antonio J. Pereira[2] and Fernando B. Luciano[1]

[1] Graduate Program in Animal Science, School of Agricultural Sciences and Veterinary Medicine, Pontifícia Universidade Católica do Paraná, São José dos Pinhais, Brazil

[2] Laboratory of Agri-Food Technology, School of Agricultural Sciences and Veterinary Medicine, Pontifícia Universidade Católica do Paraná, São José dos Pinhais, Brazil

* Corresponding author: e-mail: renata.macedo@pucpr.br

Abstract – The aim of this study was to evaluate the effect of different MAP and ages at slaughter on the instrumental color and lipid oxidation of lamb meat. *Longissimus dorsi* (LD) portions of 28 lambs, slaughtered at 4 and 8 months old, were randomly packaged under different MAP: (1 = vacuum; 2 = 69,6% N_2 + 30% CO_2 + 0,4% CO; 3 = 70% O_2 + 30% CO_2) and stored under refrigeration at 4 °C for 35 days. LD portions were weekly assessed for lipid oxidation and instrumental color (L*, a*, b*, hue and chroma). The interaction between MAP x age on meat was statistically analyzed using GLM ($p<0.05$). When the interaction was not significant, the main effects were analyzed and the means compared by Tukey´s test. Interaction between MAP x age was significant only for lipid oxidation. The increasing of the oxygen concentration in MAP associated with greater age at slaughter increased lipid oxidation ($p<0.05$). The high concentration of O_2 in MAP boosts lipid oxidation and discoloration of lamb meat during storage. The addition of CO in MAP maintains the red color of fresh lamb meat during chilled storage.

Key Words – Shelf life, Lamb, Storage

I. INTRODUCTION

Vacuum packing is traditionally used for the preservation of chilled meat, however, vacuum darkens the color of red meats, decreasing their attractiveness. In order to minimize this effect, the modification of the gas composition inside the food package could be an interesting method for meat preservation [1]. In Brazil, lamb meat is generally marketed in frozen form. Nevertheless, this procedure does not follow the current consumer´s trend for convenience [2]. Therefore the use of modified atmosphere for the preservation of chilled lamb meat could preserve its attractiveness and stimulates its consumption. Due to its chemical characteristics, chilled lamb meat is more susceptible to chemical and microbiological deterioration compared to beef, which can be efficiently preserved only by using vacuum packaging. Thus, the preservation of chilled lamb meat requires the use of more efficient packaging methods. Traditionally, the Brazilian lamb meat market is supplied by animals slaughtered at 4-6 months old (28-30 kg live weight). However, there is a trend to increase the age at slaughter and consequently the live weight at slaughter (32-36 kg) [3]. The objective of this study was to investigate the effect of different MAP and ages at slaughter on the instrumental color and lipid oxidation of lamb meat stored under refrigeration.

II. MATERIALS AND METHODS

The experiment was carried out using the *Longissimus dorsi* muscle (LD) of 28 Texel cross-breed lambs slaughtered at two different ages (4 and 8 months old) and stored under three different modified atmospheres: MAP1 = vacuum; MAP2 = 69,6% N_2 + 30% CO_2 + 0,4% CO; MAP3: 70% O_2 + 30% CO_2 [4]. LD portions (approx. 140g) were

randomly packaged in EVOH bags (permeability of 4 cm^3 O_2/m^2/day at 1 atm and 23º C (RMB Machines and Packaging, Curitiba, Brazil) using a digital packer (Selovac 200B, São Paulo, Brazil) according to the following treatments (Table 1):

Table 1. Treatments applied to lamb meat according to the modified atmosphere and age at slaughter

Atmosphere	Age at slaughter	
	4 months	8 months
MAP 1	T1	T4
MAP 2	T2	T5
MAP 3	T3	T6

T1 = Treatment 1; T2 = Treatment 2; T3 = Treatment 3; T4 = Treatment 4; T5 = Treatment 5; T6 = Treatment 6.

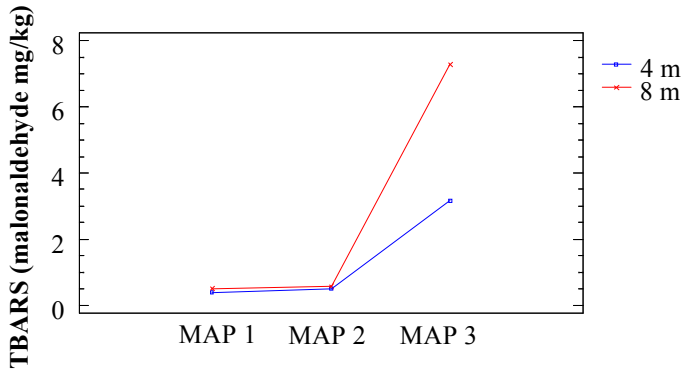
After packaging LD portions were stored under refrigeration in a BOD chamber (Fanem, CD 347, São Paulo, Brazil) at 4 ° C and analyzed for lipid oxidation and instrumental color at 0, 7, 14, 21, 28 and 35 days of storage. Lipid oxidation was determined by measuring TBARS with a spectrophotometer (Milton Roy, spectronic 21D, USA) at 538 nm [5]. The results were expressed as mg malonaldehyde (MDA) kg^{-1} meat. Instrumental color was determined on lamb samples after 30 minutes of the opening of the packages and the exposure of the samples to the atmospheric air. CIE color coordinates L*, a*, b*, hue and C* were determined using a portable colorimeter (Konica Minolta CR 410, Japan) [6], iluminant C, aperture diameter 50-53 mm and observation angle 2°.

The experimental design was completely randomized in a factorial design 2^3 with two ages at slaughter and three atmospheres. Data were analyzed using the General Linear Models with the Statgraphics Anturion XV program version 15.2.05. The individual effect of age at slaughter and MAP and their interaction were determined according to the mathematical model: $Y_{ijk}=\mu+I_i+A_j+I_i*A_j+e_{ijk}$, where: Y_{ijk} = parameter measurement, μ = mean; I_i = age at slaughter (i = 1, 2), A_j = atmosphere (j = 1, 2, 3); I_i*A_j = interaction between age at slaughter and atmosphere; e_{ijk} = error variance. When the interaction was not significant ($p>0.05$), the main effects were analyzed and means were compared by Tukey´s test ($p<0.05$).

III. RESULTS AND DISCUSSION

The interaction between age at slaughter and MAP was significant on the lipid oxidation of lamb meat ($p<0.05$). The increase of age at slaughter associated with the high O_2 concentration in MAP increased the lipid oxidation of lamb meat (Figure 1).

Figure 1. Interaction between age at slaughter (months old) and type of modified atmosphere (MAP) on the lipid oxidation of lamb meat stored during 35 days under refrigeration.



MAP 1: vacuum; MAP 2: N_2 69.6% CO_2 + 30% + 0.4% CO, MAP 3: 70% O_2 + 30% CO_2

Mean TBARS in samples of Treatment 6 (8 months old x MAP 3) was 7.29 mg MDA kg^{-1}, whereas mean TBARS in samples of T3 (4 months old, stored at the same atmosphere MAP 3), was 3.16 mg MDA kg^{-1}. Kim et al. [7] also observed a significant interaction between high oxygen MAP and age at slaughter on lipid oxidation of lamb meat. Xiong et al. [8] found increased lipid oxidation with the increasing of slaughtering age of the animal. The higher lipid oxidation in meat from older animals can also be related to the higher live weight of these animals, which can influence the fatty acid composition of lamb meat making it more unsaturated [9].

Since the value of TBARS of 2 mg MDA kg^{-1} is considered as the borderline level for the detection of off-flavor in meat, treatments subjected to both MAP1 and MAP2 showed values of TBARS below the limit after 35 days of storage. On the other hand, samples packaged with high concentration of O_2 (MAP 3) reached values of TBARS higher than 2 mg MDA kg^{-1} after 14 days of storage.

There was not significant interaction between age and MAP on the instrumental color of lamb meat. However, there was individual effect ($p<0.05$) of

age at slaughter on L * and b * values and of MAP on a*, C* and hue values of lamb meat (Table 2).

Table 2. Effect of age at slaughter and atmosphere on the instrumental color of lamb meat during 35 days of storage under refrigeration (mean ± SE)

IC	Age		Atmosphere		
	4 m	8 m	MAP 1	MAP 2	MAP 3
L*	47.29^{a}	45.01^{b}	46.12^{A}	46.27^{A}	46.06^{A}
	± 0.39	± 0.39	± 0.59	± 0.59	± 0.59
a*	21.47^{a}	20.12^{a}	20.80^{B}	23.63^{A}	17.95^{C}
	± 0.71	± 0.71	± 0.54	± 0.54	± 0.54
b*	11.02^{a}	10.24^{b}	10.35^{A}	10.85^{A}	10.70^{A}
	± 0.27	± 0.27	± 0.34	± 0.34	± 0.34
hue	27.33^{a}	27.40^{a}	26.41^{B}	24.68^{B}	31.02^{A}
	± 0.98	± 0.98	± 0.92	± 0.92	± 0.92
C*	24.15^{a}	22.66^{a}	23.25^{B}	26.01^{A}	20.96^{C}
	± 0.66	± 0.66	± 0.58	± 0.58	± 0.58

Different small letters in the same row indicate significant differences ($p<0.05$). Different capital letters in the same row indicate significant differences ($P<0.05$). IC = instrumental color. MAP 1: vacuum; MAP 2: N_2 69.6% CO_2 + 30% + 0.4% CO, MAP 3: 70% O_2 + 30% CO_2.

Meat from animals slaughtered at 4 months old showed higher L* values than from those slaughtered at 8 months old ($p<0.05$). Kim et al. [10] also observed higher L* values in meat from 3 months old lambs compared to 10 months old. The lower concentration of myoglobin in meat from younger animals could explain this effect.

The inclusion of CO in MAP (MAP 2) resulted in higher a* and C* values and lower hue values in lamb meat ($p<0.05$). On the other hand, the use of high O_2 concentration in MAP (MAP 3) caused greater discoloration of meat and less redness, indicated by the high hue and the low a* and C* values.

IV. CONCLUSION

The high oxygen concentration in MAP (70%) adversely affect the shelf life of lamb meat by higher lipid oxidation and discoloration of meat compared to the other types of MAP. Vacuum packaging and the combination of CO_2 and CO in MAP showed similar results to the stability of lamb meat by the inhibition of lipid oxidation. However the addition of CO in the gas mixture maintained the red color of the lamb meat, during 35 days of storage, making it more attractive compared to the other atmospheres.

ACKNOWLEDGEMENTS

Authors thank CNPq – Conselho Nacional de Desenvolvimento Científico e Tecnológico program MCT/CNPq 014/2010 for financial support.

REFERENCES

1. Zakrys, P.I., O'Sullivan, M.G., Allen, P. & Kerry, J.P. (2009). Consumer acceptability and physiochemical characteristcs of modified atmosphere packed beef steaks. Meat Science 81: 720-725.
2. Lauzurica, S., De la Fuente, J., Díaz, M. T., Álvarez, I., Pérez, C. & Cañeque, V. (2005). Effect of dietary supplementation of vitamin E on characteristics of lamb meat packed under modified atmosphere. Meat Science 70: 639−646.
3. Berro (2010). Carne de Cordeiro e Carne de Carneiro. Revista O Berro, Uberaba: Agropecuaria.
4. Bórnez, R., Linares, M.B. & Vergara, H. (2010). Effect of different gas stunning methods on Manchega suckling lamb meat packed under different modified atmospheres. Meat Science 84: 727-734.
5. Vyncke, W. (1970). Direct determination of the thiobarbituric acid value in trichloroacetic extracts of fish as a measure of oxidative rancidity. Fette-Seinfen Anstrichmittel 72:1084-1087.
6. ASTM Internationa. (2001). American Society for Testing and Material. Standard practice for computing the colors of objects by using the CIE system. Pennsylvania: ASTM International.
7. Kim, Y.H.B., Bocker, S., Black, C. & Rosenvold, K. (2012). Influence of lamb age and high-oxygen modified atmosphere packaging on protein polymerization of long-term aged lamb loins. Food Chemistry 135: 122-126.
8. Xiong, Y.L., Mullins, O.E., Stika, J.F., Chen, J., Blanchard, S.P. & Moody, W.G. (2007). Tenderness and oxidative stability of post-mortem muscles from mature cows of various ages. Meat Science 77:105–113.
9. Linares, M.B., Berruga, M.I., Bórnez, R. & Vergara, H. (2007). Lipid oxidation in lamb meat: Effect of the weight, handling previous slaughter and modified atmospheres. Meat Science 76: 715–720
10. Kim, Y.H.B., Stuart, A., Black, C. & Rosenvold, K. (2012). Effect of lamb age and retail packaging types on the quality of long-term chilled lamb loins. Meat Science 90: 962-966.