71st ICoMST
GIRONA - CATALONIA - SPAIN
3rd-8th August - 2025

INFLUENCE OF A LOW OXYGEN ATMOSPHERE ON COLOR AND VITAMIN CONTENT OF BEEF

J. Krell[1*], Z.Temür[1], A. Poveda-Arteaga[2], J. Weiss[1], N. Terjung[2], M. Gibis[1]

[1] Department of Food Material Science, Institute of Food Science and Biotechnology, University of Hohenheim, Stuttgart, Germany.

[2] DIL German Institute of Food Technology, Quakenbrück, Germany

*Corresponding author email: johannes.krell@uni-hohenheim.de

I. INTRODUCTION

This study aims to investigate the influence of a low oxygen atmosphere on the color stability and vitamin contents of packaged beef. A low oxygen atmosphere (e.g. 1%) is described to increase beef discoloration [1, 2]. In this study, reference atmospheres are compared to a low oxygen atmosphere in terms of color stability and vitamin levels. The vitamin contents can give further information about the overall oxidation state of the sample [3, 4]. The investigated hypothesis is: a low oxygen atmosphere results in the worst color stability and lowest vitamin E content.

II. MATERIALS AND METHODS

Fresh silversides of 3 different animals (1 day after slaughtering) were cut into 1 cm slices and were foil packaged in triplicate (3 slices/animal/packaging type) (polyamide/polyethylene, 90 µm thickness, ox. perm. 56 cm^3/m^2 bar 24h (Co. Allfo)) in vacuum (12 mbar) and different modified atmospheres (1% O_2/99% N_2, 20% O_2/80% N_2, 70% O_2/30% CO_2,). The color, α-tocopherol and retinol levels of the samples were measured on day 0 for the reference sample and after 14 days of storage at 2°C in the dark, for the packaged samples. The color measurement was performed through the foil, using a colorimeter (Co. Konica Minolta, Chroma Meter CR-400). The color difference was calculated according to ISO/CIE 11664-6:2022-08. The vitamin analysis was performed using an HPLC system (Co. Thermo Fisher, Thermo Scientific Vanquish UHPLC). The extraction and HPLC conditions were performed after Stuetz and Grebenstein [5, 6]. A short summary of important HPLC parameters is shown in Tab. 1.

Table 1 – HPLC parameters.

Column	ReproSil 80 OD-2, 3µm (250 x 4.6 mm, Dr. Maisch GmbH)
Detection	Fluorescence detector excitation/emission: α-tocopherol (325/470 nm), retinol (298/328 nm)
Flow rate	1.5 mL/min
Temperature	40°C column oven

For data evaluation, the assumptions for ANOVA were tested using a test for normal distribution (Shapiro-Wilk) and equal variances (Browne-Forsythe). If both were positive, an ANOVA with a Student-Newman-Keuls post-hoc test was performed. In the case that the equal variances were denied, an ANOVA on ranks with a Student-Newman-Keuls post-hoc test was used. Statistical significances were calculated for $p < 0.05$. The color panels were created using the L*a*b*-values and the program GIMP (Co. The GIMP Team, USA).

III. RESULTS AND DISCUSSION

The results are listed in Tab. 2. In terms of color, the vacuum packaging showed the smallest changes in color compared to day 0 with a color difference of 3.08 and an a* value of 18.75. The color differences of the other atmospheres were not significantly different with 6.02 (1%), 5.35 (20%) and 6.86 (70%). However, a look at the color panels (Tab. 1) and a*-values shows the lowest redness and a brown shift for the 1% atmosphere. The 1% oxygen atmosphere resulted in a* = 13.58, which was significantly lower than the other packages and the reference. The α-tocopherol content decreased from 0.14 µg/g in the fresh sample, to 0.10 µg/g (vacuum + 70%) and 0.06 µg/g (1% + 20%). Only traces 0.02 µg/g of retinol were found in the fresh samples and none could be detected after storage. The low initial α-tocopherol and retinol values can be explained by the fact that a lean cut of meat was used of which only lean tissue parts were extracted. Since α-tocopherol and retinol are fat soluble vitamins, that are present in animal fat but also in the cell membrane, the aim was to focus on the membrane vitamins as much as possible since the fat cells did not influence the myoglobin color directly [1, 3, 4]. By leaving out as many fat cells as possible, the overall fat content of the analyzed meat decreased. Generally, after storage, a decrease in redness and vitamins could be seen in all samples. The vacuum package preserved color and vitamin content the most. While the 1% atmosphere resulted in a brown discoloration and a low vitamin content due to increased metmyoglobin formation due to the low oxygen content [1, 2]. The 20% atmosphere resulted in the same low vitamin content, but was able preserve a more red color over time due to increased oxygenation of myoglobin [1].

Table 2 – Color, L*a*b*-values, color difference, α-tocopherol and retinol levels of the beef samples displayed as mean values ± standard deviation.

	Fresh	14 d Vacuum	14 d 1% O_2	14 d 20% O_2	14 d 70% O_2
Color					
L*(-)	$36.26^{BC} \pm 3.91$	$34.81^{C} \pm 2.36$	$35.90^{BC} \pm 2.00$	$39.27^{AB} \pm 2.04$	$39.98^{A} \pm 3.11$
a*(-)	$19.68^{A} \pm 1.48$	$18.75^{AB} \pm 1.46$	$13.58^{C} \pm 0.82$	$16.74^{B} \pm 2.25$	$17.16^{B} \pm 3.73$
b*(-)	$3.72^{D} \pm 1.00$	$2.94^{D} \pm 1.07$	$7.10^{C} \pm 0.60$	$8.11^{B} \pm 1.07$	$9.77^{A} \pm 1.01$
ΔE_{00} (-)	Reference Point	$3.08^{B} \pm 1.33$	$6.02^{A} \pm 0.94$	$5.35^{A} \pm 1.34$	$6.86^{A} \pm 2.23$
α-Tocopherol (µg/g)	$0.14^{A} \pm 0.03$	$0.10^{B} \pm 0.04$	$0.06^{C} \pm 0.02$	$0.06^{C} \pm 0.01$	$0.10^{B} \pm 0.05$
Retinol (µg/g)	$0.02^{A} \pm 0.01$	n.d.	n.d.	n.d.	n.d.

n.d. not detected (<0.01 µg/g)

The 70% atmosphere showed better color and vitamin preservation. In terms of color that was due to the increased oxygen content leading to an increased oxygenation of myoglobin [1]. In terms of α-tocopherol, that first seemed unlogical since higher oxygen content should lead to increased oxidation. However since, myoglobin is very easily oxidizable at low oxygen contents and stabilized at higher concentrations the extent of myoglobin oxidation could be the reason why the 1% atmosphere resulted in a lower α-tocopherol content than a 70% atmosphere [1].

IV. CONCLUSION

The hypothesis could be confirmed: a low oxygen atmosphere promotes beef discoloration and results in a lower α-tocopherol content. vacuum packaging is the optimal packaging to preserve the color and α-tocopherol level of beef. When dealing with discoloration problems in vacuum packages e.g. during wet-aging, the possibility of the local formation of a low-oxygen environment in the packages should be considered and avoided.

ACKNOWLEDGEMENTS

This IGF Project (22142 N) of the FEI was supported within the programme for promoting the Industrial Collective Research (IGF) of the Federal Ministry of Economic Affairs and Climate Action (BMWK), based on a resolution of the German Parliament.

REFERENCES

[1] D. A. King *et al.*, "American meat science association guidelines for meat color measurement," *Meat and Muscle Biology,* vol. 6, no. 4, 2023.

[2] D. Kropf, "Enhancing meat color stability," in *Proc. 56th Recip. Meat Conf., Columbia, MO. Natl. Livest. Meat Board, Chicago, IL*, 2003, pp. 73-75.

[3] R. T. Nassu, M. E. R. Dugan, M. Juárez, J. A. Basarab, V. S. Baron, and J. L. Aalhus, "Effect of α-tocopherol tissue levels on beef quality," (in eng), *Animal : an international journal of animal bioscience,* vol. 5, no. 12, pp. 2010-2018, 2011, doi: 10.1017/S1751731111001182.

[4] E. N. Ponnampalam, A. Kiani, S. Santhiravel, B. W. B. Holman, C. Lauridsen, and F. R. Dunshea, "The Importance of Dietary Antioxidants on Oxidative Stress, Meat and Milk Production, and Their Preservative Aspects in Farm Animals: Antioxidant Action, Animal Health, and Product Quality-Invited Review," (in eng), *Animals : an open access journal from MDPI,* vol. 12, no. 23, 2022, doi: 10.3390/ani12233279.

[5] W. Stuetz *et al.*, "Plasma carotenoids, tocopherols, and retinol in the age-stratified (35–74 years) general population: a cross-sectional study in six European countries," *Nutrients,* vol. 8, no. 10, p. 614, 2016.

[6] N. Grebenstein and J. Frank, "Rapid baseline-separation of all eight tocopherols and tocotrienols by reversed-phase liquid-chromatography with a solid-core pentafluorophenyl column and their sensitive quantification in plasma and liver," (in eng), *Journal of chromatography. A,* vol. 1243, pp. 39-46, 2012, doi: 10.1016/j.chroma.2012.04.042.