# COLOUR STABILITY AND α-TOCOPHEROL CONTENT IN BEEF *M. LONGISSIMUS DORSI* AFTER DIFFERENT PACKAGING METHODS

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***Abstract*— The objective of this study was to investigate how colour stability and α-tocopherol content of beef *M. Longissimus dorsi* (LD) were affected by skin vacuum packaging (SVP) compared to vacuum packaging (VP) and modified atmosphere packaging (MAP). The samples were first packed in vacuum for 7 days and then assigned to the different packaging methods for 7 days. Colour was then measured on samples kept in air during 5 days. The redness (*a** value) of LD was higher in MAP on day 0 than for all other packaging methods ($P<0.05$) and also higher in MAP on day 5 than in VP ($P<0.05$). The yellowness (*b** value) in SVP on day 5 was higher than in VP ($P<0.05$). Higher metmyoglobin and lower oxymyoglobin content was obtained in VP on day 5 compared with MAP and SVP ($P<0.05$). The α-tocopherol content decreased with extension of storage time with no difference between packaging methods. In conclusion, the results from our study indicated that packaging method affected colour stability. Beef packed in SVP had better colour stability than in VP. The colour of samples packed in SVP was similar with MAP at the end (day 5) of our colour detection time.**

***Key words*— Beef, Colour stability, Packaging method, α-Tocopherol**

## I. INTRODUCTION

Colour is one of the most important meat quality aspects determining consumer's purchase choice. The colour of meat is mainly due to the form of the meat pigment, myoglobin (Mb), which has three different chemical forms with specific colours, and the relative content of these chemical forms determines the visual colour of meat. Deoxymyoglobin (DeoxyMb) is purple; oxygenated myoglobin (oxymyoglobin, MbO) has bright red colour and is therefore preferred by consumers; and oxidized myoglobin (metmyoglobin, MetMb) is brownish and causes discolouration at the meat surface (Ledword, 1985).

As an antioxidant, α-tocopherol limits formation of MetMb. In animal tissues, α-tocopherol has the highest biological activity compared to other tocopherol forms (Buttriss & Diplock, 1984). α-tocopherol can compete with MbO for lipid radicals and thus inhibit the formation of MetMb. When α-tocopherol is consumed, MetMb accumulation proceeds without inhibition (Lanari, Schaefer, Liu, & Cassens, 1996).

A majority of fresh meat is packed in order to extend shelf life of meat. A variety of packaging methods offers different environments for meat products which may affect meat quality (Zakrys, Sullivan, Allen, & Kerry, 2009; Ferioli, Caboni, & Dutta, 2008; Vázquez, Carreira, Franco, Fente, Cepeda, & Velázquez, 2004). Modified Atmosphere Packaging (MAP) with the gas composition of 80% $O_2$ and 20% $CO_2$ is a common packaging method for beef in Sweden. The high oxygen content in MAP gives the beef a stable bright red colour which is preferred by consumers. However, some studies have observed negative influence of MAP on the cooked colour of meat (McMillin, 2008) and on tenderness development (Lund, Christensen, Fregil, Hviid & Skibsted, 2008). Vacuum packaging (VP) offers vacuum condition for meat, which expands the shelf life. The exudate held in wrinkles may be more susceptible to bacterial growth and is also not desirable by consumers, which could be a problem. Skin vacuum packaging (SVP) is a relatively new and advanced packaging method that inhibits the formation of wrinkles and air pockets by heating the upper cover film and making it shrink tightly around the meat. Thus, longer shelf life and slower bacterial growth could be observed in SVP compared to VP (Vázquez *et al.*, 2004).

The aim of this study was to investigate the effect of SVP on colour stability and α-tocopherol content in beef compared to MAP and VP.

## II. MATERIALS AND METHODS

*Animals and packaging*

Ten young bulls of beef breed crosses (16-20 months), from two farms were slaughtered on the same day using the standard routines of the slaughter plant. Day 1 *post mortem* one side of *M. Longissimus dorsi* (LD) on each animal was used. The pH was measured to avoid meat with pH >5.8. The LDs were packed in vacuum for 7 days at 2 ℃. The LDs

were then unpacked, pH was measured and 2-cm slices were taken from the same location. These slices were assigned to the following packaging methods: (1) Vacuum Packaging (VP); (2) Modified Atmosphere Packaging (MAP): 80% $O_2$ + 20% $CO_2$; (3) Skin Vacuum Packaging (SVP). Samples were stored at 4 ℃ for 7 days, i.e. in total 14 days *post mortem*. Samples were then exposed to air and wrapped with oxygen-permeable PVC-film (NORM PACK 115 45-1; Tempac AB, Tyresö, Sweden) for colour measurement. In addition, one slice was kept as control and was exposed to air already at day 7 when the other treatments started, i.e. in total 7 days *post mortem*.

*Colour measurements and sample collection*

Colour was measured using a Minolta CM-2500d spectrophotometer (Konica Minolta Sensing Inc., Japan) after at least 1 hour blooming (day 0) and then day 1, 3 and 5 after repacking. The average value of four measurements on the meat surface was used. The method of Krzywicki (1979) was used to calculate the relative contents of DeoxyMb, MbO and MetMb in LD. The Minolta instrument recorded reflectance values in the range of 360 nm to 740 nm with 10 nm intervals. Reflectance values that were not directly measured by the colour instrument at specific wavelengths (473, 525 and 572 nm) were calculated according to linear interpolation. Samples for analysis of α-tocopherol content were collected on day 0 and day 5 during colour measurements. These samples were stored in -80 ℃ until later analyses.

*α-tocopherol content in meat*

For the analysis of α-tocopherol, method by Högberg, Pickova, Babol, Andersson, & Dutta (2002) was used.

*Statistical analysis*

Statistical analysis was carried out with the Statistical Analysis System (Version 9.1, SAS Institute, Cary, NC, USA). The Mixed Procedure was used as statistical model with packaging methods, storage time and their interaction as fixed factors and animal as random factor.

## III. RESULTS AND DISCUSSION

*Colour stability*

*L**, *a** and *b** values were significantly affected by packaging methods and storage time ($P<0.05$, Table 1). Samples packed in MAP had higher *L** value than those packed in VP and control with exception of day 5. On day 0, the *a** value was higher when packed in MAP than in the other packaging methods and the *b** value was higher in MAP than in VP and control. On day 5, the *a** value was higher in MAP than in VP and control and the *b** value was higher in SVP than in VP and control. The *a** and *b** values of the meat increased during the first two days and then decreased within the same packaging methods except for MAP, where the *a** and *b** values decreased during the whole storage time.

Table 1 Effect of packaging method (PM) and storage time (Day) on colour stability

| | PM | Day | | | | | *P*-value | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 3 | 5 | SE | PM | Day | PM × Day |
| *L** value (lightness) | Control | $34.9^{aA}$ | $35.0^{aA}$ | $35.4^{aA}$ | $37.3^{bB}$ | 0.69 | <0.001 | 0.005 | 0.051 |
| | MAP | $36.7^{B}$ | $36.6^{B}$ | $36.9^{BC}$ | $36.7^{BC}$ | 0.72 | | | |
| | SVP | $35.4^{AB}$ | $36.3^{BC}$ | $36.1^{AC}$ | $36.2^{BC}$ | 0.79 | | | |
| | VP | $34.5^{aA}$ | $35.4^{abAC}$ | $35.6^{bA}$ | $35.7^{bAC}$ | 0.69 | | | |
| *a** value (redness) | Control | $16.1^{aA}$ | $18.0^{b}$ | $17.2^{b}$ | $15.7^{aA}$ | 0.57 | 0.001 | <0.001 | 0.007 |
| | MAP | $17.9^{B}$ | 17.8 | 17.1 | $17.2^{B}$ | 0.59 | | | |
| | SVP | $15.8^{aA}$ | $18.2^{bc}$ | $17.4^{bc}$ | $17.0^{acBC}$ | 0.66 | | | |
| | VP | $15.6^{aA}$ | $17.8^{b}$ | $16.8^{c}$ | $15.9^{aAC}$ | 0.57 | | | |
| *b** value (yellowness) | Control | $15.9^{aA}$ | $16.6^{a}$ | $16.4^{a}$ | $14.3^{bA}$ | 0.34 | 0.005 | 0.001 | 0.022 |
| | MAP | $17.0^{aBC}$ | $16.5^{ab}$ | $16.0^{b}$ | $16.0^{bBC}$ | 0.37 | | | |
| | SVP | $16.2^{AC}$ | 16.8 | 16.5 | $16.4^{B}$ | 0.46 | | | |
| | VP | $16.0^{acA}$ | $16.1^{a}$ | $15.7^{ac}$ | $15.2^{bcC}$ | 0.34 | | | |

Means with different low-case superscripts within the rows (effect of day) differ at $P< 0.05$. Means with different capital superscripts within the columns (effect of PM) differ at $P< 0.05$. SE: standard error.

The colour was measured initially and after packaging during 7 days by the use of different methods. The *a** value of LD was higher in MAP than in the other packaging methods at the beginning of colour measurement. This result was in agreement with Cayuela, Gil, Bañón, & Garrido (2004) and may be due to the higher oxygen (80%) content in MAP, which contributed to the oxygenation of myoglobin. However, other authors reported that beef discolored more rapidly in MAP than in VP (Grobbel, Dikeman, Hunt, & Milliken, 2008). The VP and SVP had more similarities because they both provided vacuum environment for the meat. The limited oxygen resulted in DeoxyMb as the main form of myoglobin in VP and SVP, which is purple in colour and might decrease consumer satisfaction. However, when the package was opened, the DeoxyMb was still able to bloom, MbO with bright red colour was formed, and this could be

the reason why the *a** value increased during the first two days (Brewer, Zhu, Bidner, Meisinger, & McKeith, 2001).

Both packaging method and storage time affected the relative content of MetMb ($P$<0.05). The relative amount of DeoxyMb was significantly different among packaging methods. On day 0, it was higher in MAP than in control but lower than in SVP and VP ($P$<0.05, Fig.1). During storage, the relative amounts of DeoxyMb in control was lower than in MAP, SVA and VP, but at the end of the storage period, the relative content of DeoxyMb did not differ among packaging methods. The relative content of MetMb was higher in MAP and control than in SVP and VP on day 0, and then during storage, MetMb content was stable in MAP but increased in the other packaging methods. Thus at the end of storage, the relative content of MetMb was lower in MAP and SVP than in control and VP. The relative content of MbO decreased with longer storage time within the same packaging method, except for SVP in which the MbO content was stable. The relative content of MbO was lower in MAP and VP than in control on day 0, but higher in MAP and SVP than in control and VP on day 5.

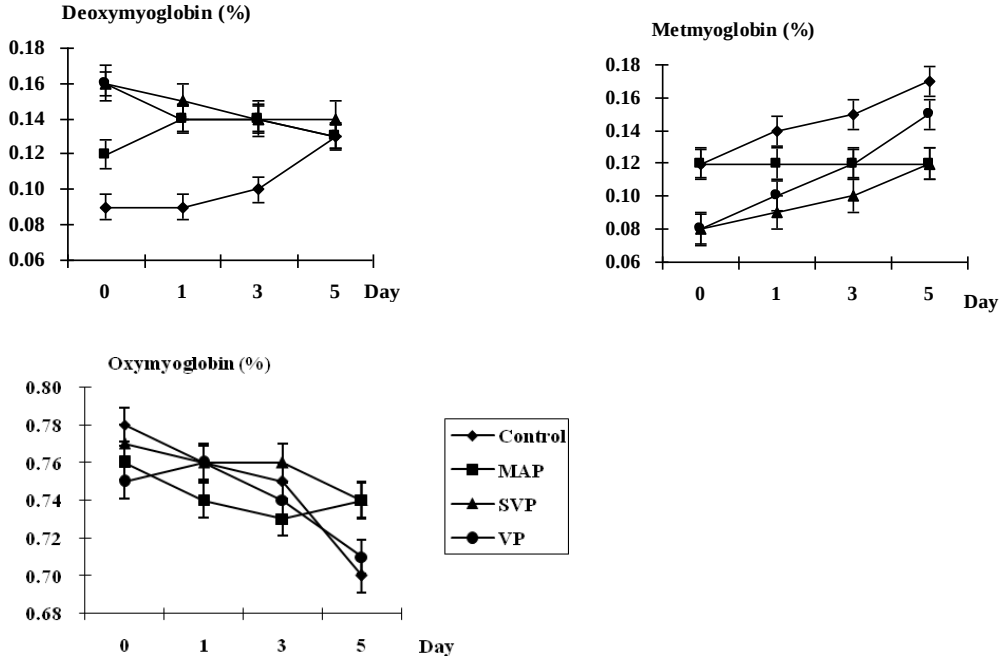


Fig. 1. Effect of packaging method on relative pigment content. Data points represent least squares means. Error bars represent positive and negative standard error.

The relative amounts of DeoxyMb, MbO and MetMb in the meat depends on the oxygen availability, the autoxidation rate of myoglobin and the MetMb reducing capacity (Mancini & Hunt, 2005). The relative amount of DeoxyMb was higher in SVP and VP on day 0, which may be due to the same anaerobic environment in these two packaging method (Vázquez *et al*., 2004). SVP is a new type of packaging method with an advantage of minimized wrinkles in the package, which may decrease the bacterial growth speed (Vázquez *et al*., 2004). The reduced risk of bacterial growth may be beneficial for colour stability and this may explain why DeoxyMb was more stable in SVP than in VP during storage, resulting in higher MbO and lower MetMb in SVP than in VP at the end of storage time.

Table 2 Effect of packaging method (PM) and storage time (Day) on α-tocopherol content

| PM | α-tocopherol content (μg/g) | | | *P*-value | | |
|---|---|---|---|---|---|---|
| | Day 0 | Day 5 | SE | PM | Day | PM × Day |
| Control | 2.58[a] | 2.16[b] | 0.13 | 0.234 | <0.001 | 0.119 |
| MAP | 2.27 | 2.12 | 0.14 | | | |
| SVP | 2.57[a] | 1.99[b] | 0.16 | | | |
| VP | 2.46 | 2.23 | 0.13 | | | |

Means with different low-case superscripts within the rows (effect of day) differ at $P$< 0.05. SE: standard error.

*α-Tocopherol content*

α-Tocopherol contents in LD decreased with longer storage time ($P$<0.05, Table 2), but with no difference between packaging methods. SVP and VP are similar packaging methods. However, α-tocopherol significantly decreased in SVP during storage time and at the same time higher MbO was observed in SVP on day 5 compared to VP. The mechanism of α-tocopherol protecting oxymoglobin is not well understood. A model was proposed with the general hypothesis that α-tocopherol indirectly maintained oxymyoglobin by direct inhibiting lipid oxidation (Schaefer, Liu, Faustman, & Yin, 1995). Our result further confirmed that α-tocopherol might influence colour stability (Faustman, Chan, Schaefer, & Havens, 1998).

## IV. CONCLUSION

The results from this study indicated that packaging methods greatly affect colour stability. Samples of *Longissimus dorsi* packed in SVP had better colour stability than in VP. The colour of samples that were packed in SVP was at the same level as in MAP at the end (day 5) of our colour detection time.

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