

RELATIONSHIPS BETWEEN DIFFERENT
COLOUR PARAMETERS FROM REFLECTANCE
MEASUREMENTS ON BOVINE MUSCLES

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INTRODUCTION

Reflectance measurement is a useful method of studying meat colour and colour changes. The measurements may be evaluated in different ways depending on the instrument used or the purpose of the study. If the aim is to describe the colour or the colour change objectively, colour scales like the Hunter L,a,b or the CIE L*,a*,b* are useful. On the other hand, if it is important to know the reason for the colour change, the reflectance at certain wavelengths can be used to calculate the different forms of myoglobin.

The colour of meat depends on which of the three forms of myoglobin, deoxymyoglobin (Mb), oxymyoglobin (MbO) and metmyoglobin (MetMb), that dominates on the meat surface. When the meat is exposed to oxygen, Mb converts to MbO and the colour changes from purple to bright red, which is called blooming. Myoglobin is oxidized to MetMb when the meat is stored in air and the colour then changes to brown.

Each form of myoglobin has a specific reflectance curve and the curves cross each other at certain wavelengths. These wavelengths in common can be used to quantify the myoglobin forms (Hunt, 1980). The reflectance values are converted to K/S-values in order to obtain a linear plot with the concentrations of the myoglobin forms (Stewart *et al.*, 1965). To minimize the effect of differences in structure, pH, myoglobin or fat content the ratio between two wavelengths is often used (Hunt, 1980). K/S610 / K/S525 to quantify MbO and K/S572 / K/S525 to quantify MetMb.

The calculation of percent of MbO and MetMb also requires values for 0% and 100% MbO and MetMb, respectively.

Reflectance values without the calculation of K/S-values, for example R630-R580 (Van den Oord and Wesdorp, 1971; Claus *et al.*, 1984; Unruh *et al.*, 1986; Renerre and Labas, 1987), R630/R525 (Claus *et al.*, 1984) as well as Hunter a-value, hue (a/b) and chroma $(a^2 + b^2)^{1/2}$ (Ledward *et al.*, 1986) and CIE L*, a*, b* values (Unruh *et al.*, 1986) have been used to study colour changes on meat.

If MbO or MetMb could be predicted by any other colour parameter directly measured by the instrument, there would be no need for time consuming calculations of K/S-values. Sometimes it is not necessary to know the real quantities of the different forms of myoglobin. It could be enough to use a colour parameter correlated to the quantities of the myoglobin forms. A prerequisite is that the relationship is linear. Of course, this colour parameter would not give values of universal validity, because the results would depend on the instrument and the measuring conditions used. Still, it could be useful in many experiments, for example, to compare the colour stability between different samples within the same study, if one is aware of its limitations.

Ledward *et al.*, (1986) found linear relationships between the accumulation of MetMb and Hunter a-value, hue and chroma respectively. However, the conclusion was that it would be difficult to predict the MetMb content from these colour parameters as the relationships differed among the groups studied, fresh/aged and electrically stimulated/nonstimulated meat.

The objective of this study was to evaluate whether MbO and MetMb could be predicted by any other colour parameter. The colour of beef was measured on a Hunterlab Color Quest

instrument during a long-duration storage. The results of the measurements were given in percent reflectance as well as in the CIELAB values. The relationships between the colour parameters R630/R580, R630-R580, R630/R525, a^* , b^* , b^*/a^* , C^* and K/S610 / K/S525 (MbO) and K/S572 /K/S525 (MetMb), respectively, were evaluated.

MATERIALS AND METHODS

Beef longissimus dorsi (LD) and psoas major (PM) were aged in vacuum at 4°C for 0,1,2,3,5,8,15 weeks and in 100% carbon dioxide at 2°C for 0,2,5,8,11, 15,31 weeks. The meat was analysed for blooming and colour stability at each period of storage. The reflectance was measured immediately after cutting and every five minutes for one hour in order to follow the colour changes when Mb converted to MbO, i.e. blooming. The meat was also stored in air at 4°C for five days and the reflectance was measured once a day in order to follow the oxidation of myoglobin to MetMb.

The meat was cut into 2 cm thick slices, placed in a petri dish and covered with an oxygen permeable film. The reflectance was measured on a Hunterlab Color Quest instrument (specular excluded, 10° standard observer, CIELAB (1976) colour scale, illuminant D65 and 25 mm measuring aperture). K/S610 / K/S525 was calculated as a measure of MbO and K/S572 / K/S525 as a measure of MetMb. The following colour parameters were used: R630/R580, R630-R580, R630/R525, a^* , b^* , b^*/a^* , and $C^* = (a^{*2} + b^{*2})^{1/2}$. All the values were calculated from the same reflectance measurement.

Regression analysis was used for statistical evaluation of the relationships between the different colour parameters and MbO and MetMb, respectively.

RESULTS

Linear relationships were found between all the colour parameters and K/S610 / K/S525 (MbO) during blooming. The correlations were high ($r = 0.74-0.99^{***}$) for all except b^*/a^* , where r was 0.20^* . Correlation coefficients for the different colour parameters are shown in Table 1.

The relationships were quadratic between all the colour parameters and K/S610 / K/S525 (MbO) during oxidation of myoglobin to MetMb, with high correlations ($r = 0.84-0.99^{***}$). Correlation coefficients for the different colour parameters are shown in Table 1.

The relationships were quadratic between all the colour parameters and K/S572 / K/S525 during oxidation of myoglobin to MetMb except for a^* , where a linear relationship was found. The correlations were all high ($r = 0.82-0.97^{***}$). Correlation coefficients for the different colour parameters are shown in Table 2.

Diagrams 1-7 show the relationships between K/S610 / K/S525 (MbO) and the different colour parameters during blooming and oxidation respectively. A value of 0.20 (K/S610 / K/S525) corresponds to 100% MbO and a value of 0.65 to 0% MbO.

Diagrams 8-14 show the relationships between K/S572 / K/S525 (MetMb) and the different colour parameters during oxidation. A value of 0.65 (K/S572 / K/S525) corresponds to 100% MetMb and a value of 1.40 to 0% MetMb.

Table 1. Regression between K/S610 / K/S525 (MbO) and different colour parameters during blooming and oxidation respectively. *** $P \leq 0.001$, * $P \leq 0.05$.

Colour parameter	Blooming (n=150)		Oxidation (n=600)	
	Linear relationship Regr.coeff.	Sign.	Quadratic relationship Regr.coeff.	Sign
R630/R580	0.885	***	0.972	***
R630-R580	0.870	***	0.959	***
R630/R525	0.742	***	0.967	***
a*	0.950	***	0.989	***
b*	0.916	***	0.844	***
b*/a*	0.195	*	0.913	***
C*	0.989	***	0.992	***

Table 2. Regression between K/S572 / K/S525 (MetMb) and different colour parameters during oxidation of myoglobin to MetMb. *** $P \leq 0.001$.

Colour parameter	Oxidation (n=600)		
	Type of regression	Regr.coeff.	Sign.
R630/R580	Quadratic	0.965	***
R630-R580	"	0.969	***
R630/R525	"	0.921	***
a*	Linear	0.927	***
b*	Quadratic	0.819	***
b*/a*	"	0.833	***
C*	"	0.934	***

DISCUSSION

All the measurements were used to evaluate the relationships, since there were small differences between the different muscles (LD and PM) as well as between the different storage systems (vacuum and carbon dioxide). Ledward *et al.*, (1986) found linear relationships with high correlation coefficients between the accumulation of MetMb and the Hunter a-value, hue (a/b) and chroma $(a^2 + b^2)^{1/2}$, respectively. However, the relationships differed among the groups studied (fresh/aged and electrically stimulated/nonstimulated meat) and the conclusion was that it would be difficult to predict the MetMb content from these colour parameters. An explanation for the

differences between the study of Ledward *et al.*, (1986) and the present one could be that this study involves many more observations and extends over a wider range of MetMb, 0% to 100% as opposed to 0% to 50%. Linear relationships can more easily be found in a more limited range of MetMb.

The relationships between MbO or MetMb and some colour parameter ought to be linear if myoglobin changes are to be able to be predicted by this colour parameter, without using any equation to calculate the myoglobin quantity. The results show that all relationships during blooming were linear. However, only a* versus MetMb was

linear during oxidation. The a^* -value may thus be used to predict either MbO during blooming or MetMb during oxidation, that is when only two of the three myoglobin forms change. In many cases, all of the three forms of myoglobin are involved when the colour of meat changes. For example, newly slaughtered meat or DFD-meat with a high pH does not bloom completely. Consequently, there is a change in Mb as well as in MbO and MetMb during oxidation, and the a^* -value would not be of use.

The change in the a^* -value was different during blooming and oxidation. The a^* -value increased during blooming and decreased during oxidation. The reason for this is that the colour changes from purple to red during blooming and from red to brown during oxidation and that the a^* -value describes the change in redness. Thus, a decrease in the a^* -value could mean either a deoxygenation of MbO to Mb or an oxidation to MetMb. This means that the a^* -value only describes the change in the red colour, not how the myoglobin changes, when all the three myoglobin forms are involved.

CONCLUSIONS

The a^* -value may be used to predict the myoglobin changes, either during blooming or during oxidation to MetMb. The prerequisite for these relationships is that only two of the three myoglobin forms change during the measurements.

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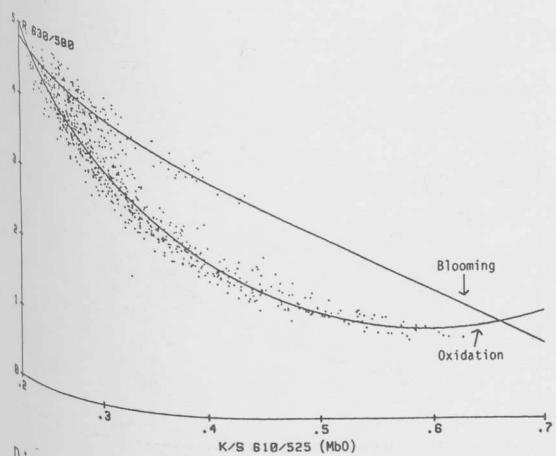


Diagram 1. Relationships between R580/R630 and K/S610 / K/S525 during blooming (n= 150) and oxidation (n= 600).

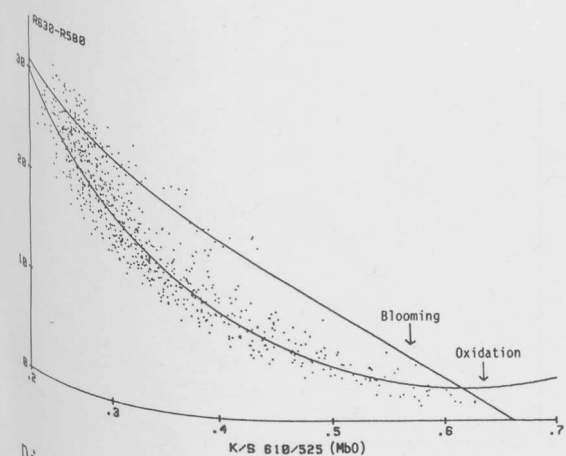


Diagram 2. Relationships between R630-R580 and K/S610 / K/S525 during blooming (n= 150) and oxidation (n= 600).

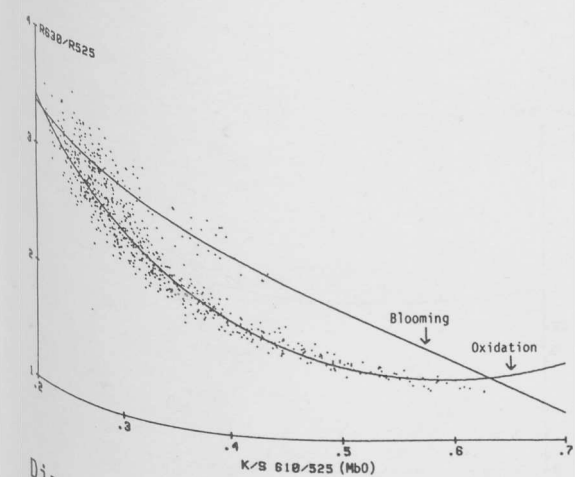


Diagram 3. Relationships between R630/R525 and K/S610 / K/S525 during blooming (n= 150) and oxidation (n= 600).

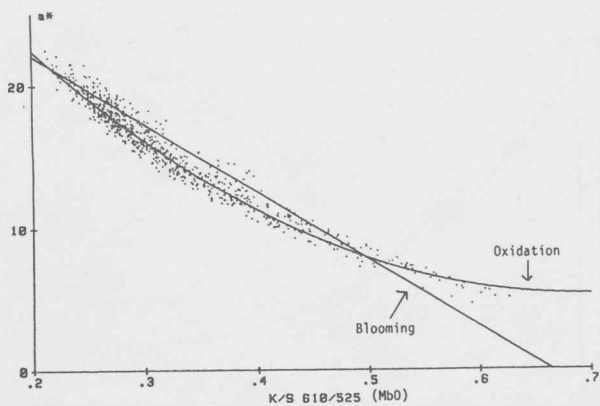


Diagram 4. Relationships between a^* and K/S610 / K/S525 during blooming (n= 150) and oxidation (n= 600).

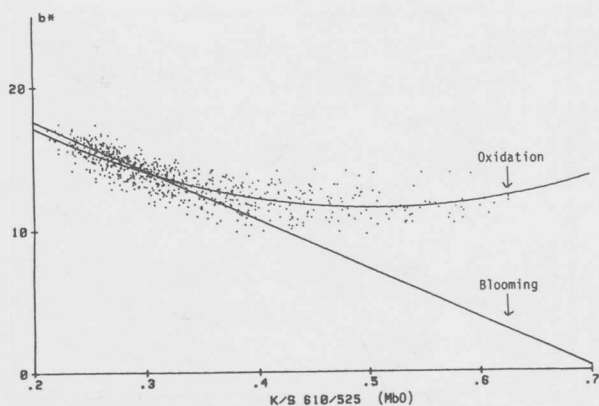


Diagram 5. Relationships between b^* and K/S610 / K/S525 during blooming (n= 150) and oxidation (n= 600).

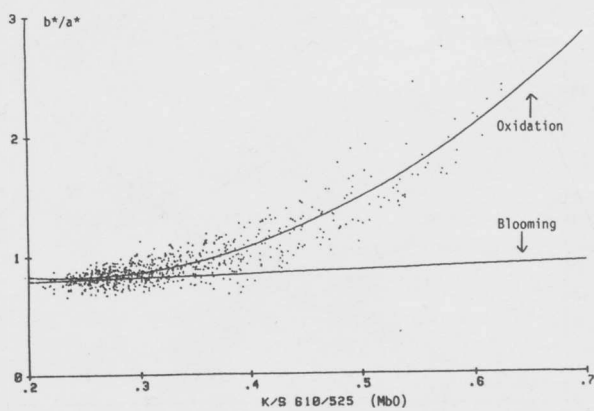


Diagram 6. Relationships between b^*/a^* and K/S610 / K/S525 during blooming (n= 150) and oxidation (n= 600).

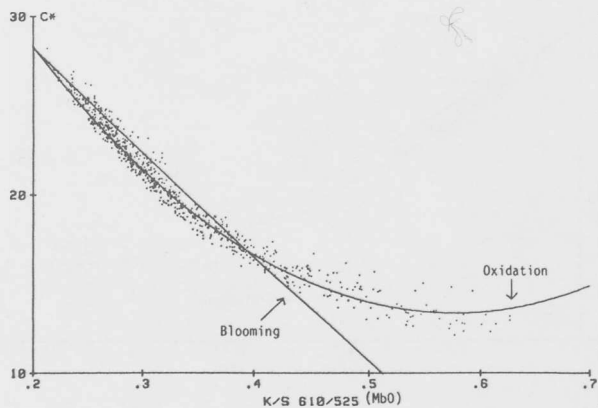


Diagram 7. Relationships between C^* and $K/S610 / K/S525$ during blooming ($n= 150$) and oxidation ($n= 600$).

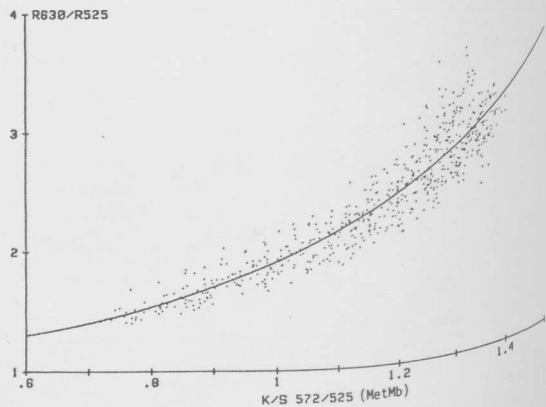


Diagram 10. Relationships between $R630/R525$ and $K/S572 / K/S525$ during oxidation ($n= 600$).

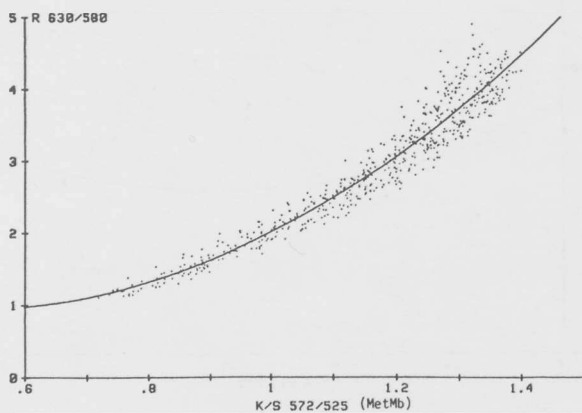


Diagram 8. Relationships between $R630/R580$ and $K/S572 / K/S525$ during oxidation ($n= 600$).

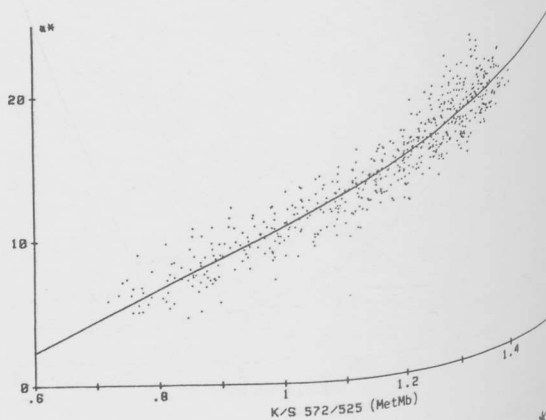


Diagram 11. Relationships between a^* and $K/S572 / K/S525$ during oxidation ($n= 600$).

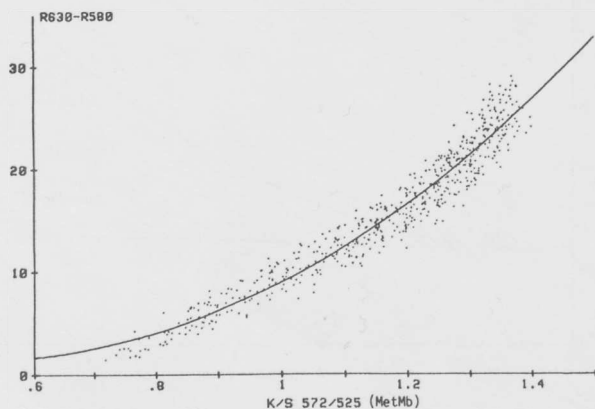


Diagram 9. Relationships between $R630-R580$ and $K/S572 / K/S525$ during oxidation ($n= 600$).

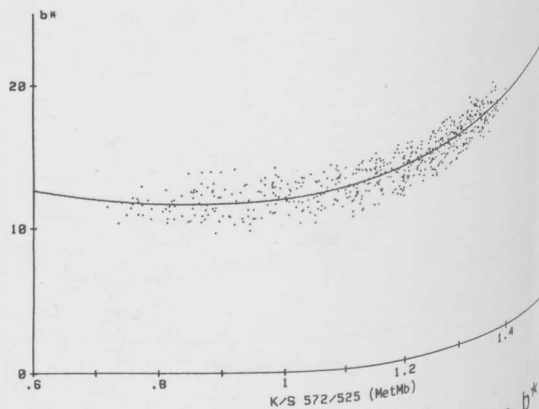


Diagram 12. Relationships between b^* and $K/S572 / K/S525$ during oxidation ($n= 600$).

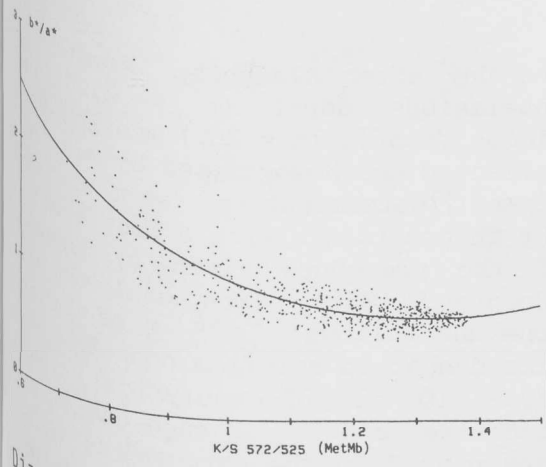


Diagram 13. Relationships between b^*/a^* and $K/S572 / K/S525$ during Oxidation (n= 600).

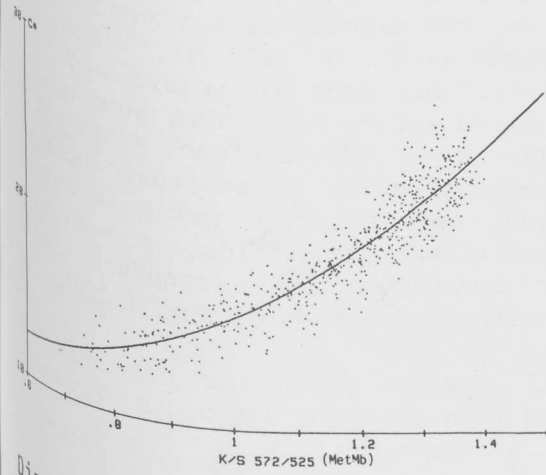


Diagram 14. Relationships between C^* and $K/S572 / K/S525$ during oxidation (n= 600).