PE4.85 Influence of post mortem glycolysis and cooling on colour and colour stability in different muscles of Belgian Blue beef 296.00

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***Abstract*—Beef from double-muscled Belgian Blue cattle is characterized by fast glycolysis and slow temperature fall post mortem, which may affect the colour stability in deeper muscles resulting in e.g. two-toning and pale colour. In this study, the longissimus dorsi (LD) muscle at 8 cm depth, the inner biceps femoris (IBF) at 10 cm depth and the outer biceps femoris (OBF) at 2 cm depth was studied in 197 young bulls of this breed. The pH fall was extremely fast in the LD and IBF within the first 5 hours post mortem (pm) with values as low as 5.56 and 5.38 respectively. Together with the slow cooling rate this resulted in heat shortening (pH < 6 and temperature > 35 °C) for both the LD and the IBF muscle. On the other hand, in the OBF muscle pH and temperature at 5 hours pm were 6.59 and 20.2 °C respectively without occurrence of heat shortening. In the IBF muscle the initial lightness was significantly higher compared to the OBF muscle (50.1 vs. 36.9), illustrating the problem of two-toning in the BF muscle. The influence of variation in pH as well as temperature during the first 5 h pm on colour and colour stability was greater for the LD than for the IBF and OBF muscle. To fasten cooling of the BF muscle, hot boning of this muscle from one carcass side was executed on 3 young bulls. After 5 hours pm the pH value was 5.93 and 5.42 respectively in the hot and cold boned IBF muscle and there was no problem of heat shortening in the hot boned side. The difference in lightness between the hot boned OBF and IBF muscle was significantly reduced (38.3 vs. 35.1). Hot boning of the BF muscle can be seen as an appropriate solution for faster chilling and tackling problems with colour stability.**

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***Index Terms*— colour stability meat, Double-muscled Belgian Blue, glycolyse, hot boning.**

I. INTRODUCTION

Problems with pale and two-toned colour and reduced colour stability of meat from Belgian Blue beef cattle, mainly in the deeper parts of the hindquarter, are regularly reported in commercial practice. The problem is complex and undoubted multifactorial. There are large differences in colour stability between muscles [1]. In addition, muscle tissue and meat quality of double-muscled Belgian Blue cattle differs in many aspects from meat of conventional breeds [2,3]. The more glycolytic fiber type in combination with the larger muscle mass of these animals results in faster glycolysis and slower cooling post mortem (pm) compared to carcasses of non double-muscled and lighter animals. Particularly in the deeper muscles of the hindquarter this may provoke heat shortening (pH < 6 and temperature > 35 °C; [4]) and the occurrence of pale and two-toned colour. De Smet *et al.* [5] previously stated that heat shortening was at least partly responsible for two-toning in deeper muscles of Belgian Blue beef. In a study of Sammel et al. [6] the colour stability of the semimembranosus muscle was improved by partial hot-boning this muscle. The influence of complete hot boning on the colour traits of affected muscles deserves further research.

The objective of this study was to investigate the influence of glycolysis and cooling post mortem, both determining the period of heat shortening, on the colour and colour stability properties of meat from deeper laying muscles of bovine carcasses. In addition, the influence of hot boning, i.e. removing the meat from the skeleton prerigor resulting in faster cooling, was evaluated for its effect on the colour and colour stability of meat.

II. MATERIALS AND METHODS

A. Animals and diets

A total of 197 double-muscled Belgian Blue young bulls (carcass weight: 504 ± 42 kg; age: 21 ± 2 months) from commercial farms in Belgium were slaughtered and sampled in four different abattoirs. All carcasses were classified in class S for conformation and in class 2 for fat covering according to the SEUROP carcass classification system.

B. pH and temperature measurements

Temperature and pH were measured at 1, 3, 5 and 48 hours pm in the longissimus (LD) muscle at 8 cm depth, in the inner biceps femoris (IBF) at 10 cm depth

and the outer biceps femoris (OBF) at 2 cm depth.

C. Sampling and simulated display

At 48 hours pm, samples of the LD, IBF and OBF were taken, wrapped in oxygen permeable foil and displayed at 4°C under fluorescent light (approximately 1200 lux).

D. Colour measurements

Colour was measured on 118 samples of LD muscle and 124 samples of BF muscle. Colour parameters were measured with a Hunterlab Miniscan colour meter (D65 light source, 10° standard observer, 45°/0° geometry, 1-inch light surface, white standard) at 0 hours (d0) and 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 days of display to assess colour stability [7].

CIE L^*-values (lightness), a^*-values (redness), and spectral reflectance (400-700 nm) data were collected. Spectral data were used to calculate metmyoglobin (MetMb) values, expressed in %MetMb, as described by Krzywicki [8]. Initial L^* and a^* values (respectively L^*(d0) and a^*(d0)) were used to characterize the colour of the meat. The colour stability of the meat was evaluated from the slope of the linear regression describing the decline in a^* value and the increase in %MetMb during the display from day 1 until day 7, expressed respectively as Ba^* and B%MetMb. Two-toning in BF, expressed as the difference between L^*(d0)IBF and L^*(d0)OBF, was also used as an index for colour acceptance.

E. Hot boning

Hot boning was performed on 3 double-muscled Belgian Blue young bulls (carcass weight: 508 ± 54 kg; age: 22 ± 1 month). The carcasses were classified in class S for conformation and in class 2 for fat covering according to the SEUROP carcass classification system. Within 2 hours after slaughter, the BF muscle of one carcass side was completely cut out to allow faster cooling of the muscle, whereas the other carcass side was left intact and served as control. The hot boned BF muscle was kept dark and stored vacuum at 12°C during the first 5 h pm and then at 4 °C. At 48 hours pm the sample was wrapped in oxygen permeable foil and displayed at 4°C under fluorescent light (approximately 1200 lux).

III. RESULTS AND DISCUSSION

In Figure 1 and 2 the average pH and temperature fall respectively is shown (bars represent standard deviations). The pH fall was extremely fast with average values as low as 5.56 and 5.38 at 5 hours pm in the LD and the IBF respectively. On the other hand, the decline of the temperature in these muscles was rather slow with average values of 29.1 °C and 36.5 °C in the LD and the IBF respectively at 5 hours pm. The average duration of heat shortening was estimated to be approximately 1.1 hours for the LD and 3.8 hours for the IBF muscle. On the other hand, average pH and temperature at 5 hours pm was 6.59 and 20.2 °C respectively in the OBF. Hence, no heat shortening occurred in the OBF.

The average initial L^* values for the LD, OBF and IBF muscle were 37.8, 36.9 and 50.1 respectively. In the IBF muscle the initial lightness was significantly higher compared to the OBF muscle. This illustrates the problem of two-toning in the BF muscle. During 10 days of display the L^* value slightly increased in all muscles and was the most significant for the IBF muscle (data not shown). The average initial a^* values did not differ much for the LD, OBF and IBF and were 20.8, 20.2 and 20.9 respectively. During the display all muscles showed a decline in redness which was most significant for the IBF muscle (data not shown). For %MetMb a similar but opposite trend as for redness was found in the LD, OBF and IBF muscle.

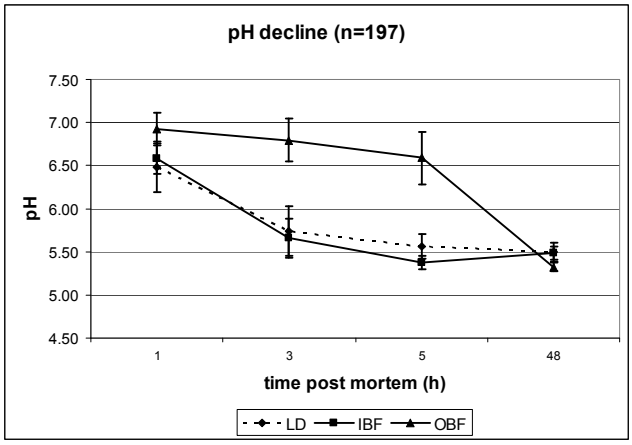

Figure 1. pH decline for longissimus dorsi (LD) and inner and outer biceps femoris (IBF and OBF) muscle

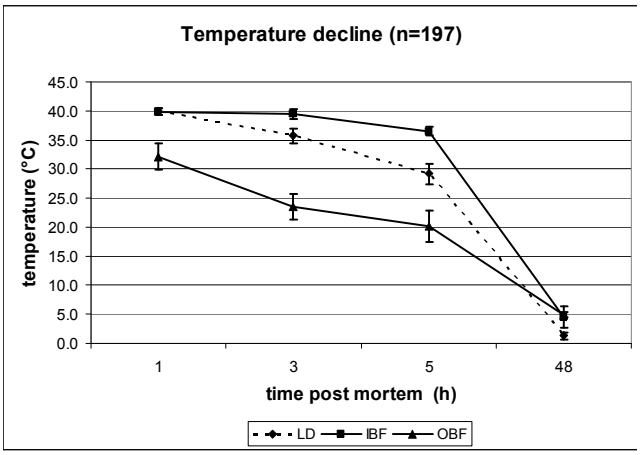

Figure 2. Temperature decline for longissimus dorsi (LD) and inner and outer biceps femoris (IBF and OBF) muscle

To tackle the problem of heat shortening, particularly in the deeper muscles, a better understanding of the influence of fast glycolysis and cooling pm on colour traits is needed. In Table 1 the Pearson correlation coefficients between pH and colour and colour stability parameters for the LD, OBF and IBF are given. For the LD muscle, pH showed some relationships with the colour parameters. Negative correlation coefficients between pH at 1, 3 and 5 h pm and the initial L^* value indicated that the higher the pH value the lower the initial lightness value for the LD. Steen *et al.* [9] also found significant correlations of L^* with pH values (measured at 10 cm depth) at 1, 3 and 24 h pm in the longissimus thoracis muscle of 153 Belgian Blue White bulls. The relationships between the pH values and the initial a^* value were similarly negative, but much weaker and not significant. In addition, the higher the pH value within the first three hours post mortem the smaller the change in a^* and %MetMb values. Indeed, the decline in pH showed a negative and positive correlation coefficient with the change in a^* and %MetMb values respectively. For the OBF muscle, negative correlations between pH and the initial a^* value were also found. Similar to the LD muscle, a negative correlation between the pH decline in the first three hours and the change in a^* value and a positive correlation with the change in %MetMb was apparent. On the other hand, a positive correlation between pH at 1 h pm and the change in %MetMb was found, which is difficult to explain. In the IBF muscle, correlation coefficients were generally weaker and different compared to the LD and OBF. The decline in pH only showed a positive correlation with the initial L^* value. A negative correlation of pH with change in %MetMb at 3h pm and 2-toning at 5h pm was also found.

In general, the influence of pH during the first 5 hours postmortem on colour and colour stability was greater for the LD than for the BF muscle, and greater for the OBF than for the IBF.

Table 1. Pearson correlation coefficients between pH and colour and colour stability parameters

		pH (1h)	pH (3h)	pH (5h)	ΔpH (1-3h)
		n[a]=91	n=102	n=102	n=91
LD	L^*(d0)	**-0.38*** **	**-0.37*** **	**-0.23***	0.00
	a^*(d0)	-0.16	-0.16	-0.10	0.08
	Ba^*	**0.36*** **	**0.55*** **	0.17	**-0.23***
	B%MetMb	**-0.25***	**-0.50*** **	-0.16	**0.30****
		n=26	n=26	n=26	n=26
OBF	L^*(d0)	0.09	0.09	0.31	-0.02
	a^*(d0)	-0.29	-0.19	**-0.40***	-0.04
	Ba^*	-0.11	0.12	0.29	-0.31
	B%MetMb	**0.46***	0.14	0.07	0.32
	2-toning	0.05	0.00	-0.08	0.05
		n=84	n=100	n=102	n=84
IBF	L^*(d0)	0.06	-0.16	-0.09	**0.32****
	a^*(d0)	0.00	0.09	-0.03	-0.07
	Ba^*	0.00	0.13	-0.02	-0.11
	B%MetMb	-0.02	**-0.21***	0.14	0.11
	2-toning	0.11	-0.03	**-0.22***	0.21

[a] number of animals

* p< 0.05, ** p< 0.01 and *** p< 0.001

In Table 2 the Pearson correlation coefficients between temperature and colour and colour stability parameters for the LD, OBF and IBF muscle are given. For the LD muscle, temperature showed in general a good relationship with the colour parameters. Positive correlation coefficients between temperature at 1, 3 and 5 h pm and initial L^* value indicated that the higher the temperature the higher the initial lightness of the LD was. Correlations of both temperature and temperature decline with initial redness cannot be easily explained. Temperature at 1, 3 and 5 h pm was negatively and positively related to the shift in a^* value and %MetMb respectively. The decline in temperature showed a positive and negative correlation coefficient with the change in a^* and %MetMb values respectively. So, the higher the temperature fall, the smaller the changes in redness and %MetMb. For the OBF muscle, similar as for the LD but much weaker relationships were

found between the temperature values and the initial *a** value. However, temp(3h) was negatively related to the change in %MetMb, which is difficult to explain. The opposite relationship would be expected such as in the LD muscle. A negative correlation between the decline in temperature and 2-toning indicated that the higher the temperature fall in the OBF muscle the lower the value of 2-toning. In the IBF relationships between temperature and colour parameters were very poor, however with a positive relationship between temperature at 3 and 5 h pm and the increase in % MetMb, in line with the LD.

Table 2. Pearson correlation coefficients between temperature and colour and colour stability parameters

		temp (1h)	temp (3h)	temp (5h)	Δtemp (1-5h)
LD		n[a]=93	n=102	n=102	n=93
	*L**(d0)	**0.41*****	**0.24***	**0.23***	-0.15
	*a**(d0)	0.06	**0.20***	**0.21***	**-0.28****
	B*a**	**-0.36*****	**-0.53*****	**-0.45*****	**0.41*****
	B%MetMb	**0.31****	**0.50*****	**0.42*****	**-0.39*****
OBF		n=26	n=26	n=26	n=26
	*L**(d0)	0.02	0.09	-0.31	0.22
	*a**(d0)	-0.10	**0.40***	**0.42***	-0.36
	B*a**	0.03	0.13	-0.13	0.11
	B%MetMb	-0.24	**-0.47***	-0.10	-0.12
	2-toning	-0.24	-0.28	0.27	-0.36
IBF		n=87	n=102	n=101	n=86
	*L**(d0)	**0.22***	0.07	0.11	-0.02
	*a**(d0)	-0.14	-0.08	-0.08	-0.04
	B*a**	-0.08	-0.12	-0.09	-0.07
	B%MetMb	0.15	**0.22***	**0.20***	0.07
	2-toning	0.04	-0.03	-0.04	-0.02

[a] number of animals
* p< 0.05, ** p< 0.01 and *** p< 0.001

In general, variation in both temperature at different time points pm and temperature decline mainly affected the colour and colour stability in the LD muscle. The effect of temperature variation was rather small on the variation of colour and colour stability in the OBF and IBF muscles. Hence, temperature plays an important role on the colour traits of this muscles. It only suggests that the current cooling practices do not allow to steer the temperature decline sufficiently to influence the colour and colour stability in OBF and IBF muscle. Therefore hot boning of the BF muscle could be an appropriate solution for faster chilling of the hindquarter, and improving the colour and colour stability.

In the discussion above, the influence of pH and temperature was considered separately. However, there is an important relationship between temperature and pH. For example, negative correlation coefficients between temperature and pH at 1h pm for the LD (r=-0.53), OBF (r=-0.50) and IBF (r=-0.39) muscle indicated that the higher the temperature the lower the pH. For the LD muscle, a negative relationship (r=-0.22) between the temperature fall and the pH decline was also found. As a consequence, the temperature cannot be seen independent from the pH.

In Figure 3 en 4 the average pH and temperature fall for the hot and cold boned OBF and IBF muscle are given respectively (bars represent standard deviations). Cold boning refers to boning of the carcass 48 hours after slaughter. For the IBF muscle, hot boning influences the pH fall in a positive way. After 5 hours pm the pH value was 5.93 and 5.42 respectively in hot and cold boned IBF muscle. The pH value of the OBF muscle at 5 h pm was lower when hot compared to cold boned, 5.92 vs. 6.58. The temperature fall of the hot boned IBF muscle follows more or less the same pattern as the hot boned OBF muscle. As a consequence, there was no period of heat shortening both in OBF and IBF muscle when hot boned. The average duration of heat shortening in the cold boned IBF muscle was estimated to be approximately 3.9 hours.

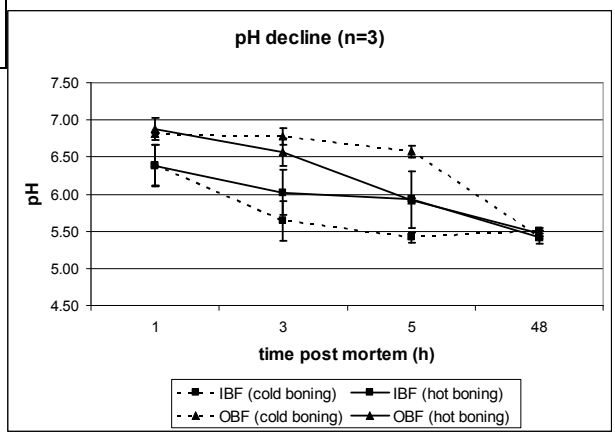

Figure 3. pH decline for inner and outer biceps femoris (IBF and OBF) muscle

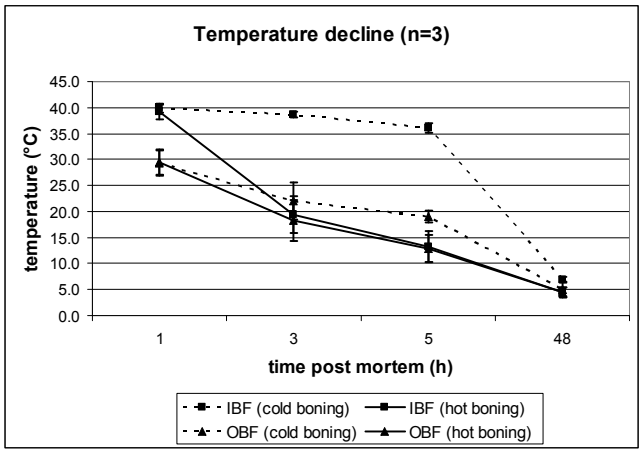

Figure 4. Temperature decline for inner and outer biceps femoris (IBF and OBF) muscle

The average initial *L** values for the OBF and IBF muscle cold versus hot boned were 49.0 vs. 34.8 and 38.3 vs. 35.1 respectively (data not shown). The difference in lightness between the OBF and IBF muscle was significantly reduced and hereby the problem of two-toning. For the IBF muscle the decrease in redness and the increase in %MetMb was also reduced when hot boned. The first results of the effect of hot boning on colour and colour stability of the BF muscle showed that the problem of two-toning was strongly reduced. Hence, hot boning will be repeated on more carcasses to confirm these findings.

IV. CONCLUSION

In double-muscled Belgian Blue young bulls, heat shortening occurs in a moderate way in the LD and more severe in the IBF muscle, resulting in a pale colour and two-toning in the BF. The influence of variation in pH as well as temperature fall pm on colour and colour stability was greater for the LD than for the OBF and IBF muscle under normal cooling practices. Hot boning of the BF muscle can be seen as an appropriate solution for faster chilling and tackling problems with colour stability.

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