COLOR DEVELOPMENT OF DIFFERENT ULTIMATE PH BEEF DURING EARLY POSTMORTEM TIME

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Abstract- Eighteen cattle from a lot of ninty were selected to examine the beef color development of three ultimate pH groups (5.4-5.8; 5.8-6.1; 6.1-7.0) within 24h postmortem. pH, temperature, and *L* a* b values were measured at 45min, 3h, 6h, 12h and 24h postmortem, and again after 20 min exposure to air (bloom time) at each interval. Results showed that ultimate pH, postmortem time, blooming and the interaction of ultimate pH and postmortem time had significant effects on *a*, b*, C** and *h** color values. High ultimate pH beef had lower ($P < 0.05$) *a*, b*, C** and *h**. All CIE values increased as postmortem time extended, especially from 12h to 24h. Except for *L** value, all CIE values of each pHu group all increased ($P < 0.05$) significantly after blooming. No difference of *L*, a*, b** or *C** values were found between high ultimate pH beef at 24h and pre-rigor muscle at 45 min postmortem, while the *h** was ($P < 0.05$) different. This is apparently the first study to monitor beef color changes during the early postmortem period among muscles of different ultimate pH (pHu) compared to pre-rigor muscle color. Further studies were conducted to investigate the underlying merchanisms of color development during the early postmortem period.**

Keywords-color, DFD beef, early postmortem time, ultimate pH

I. INTRODUCTION

Color is the most important factor influencing the consumers` willingness to buy fresh beef [1]. High ultimate pH (pHu) beef, also called dark cutting beef or DFD (Dark, Firm, Dry) beef always exhibits a very dark color, decreasing the accepantce by consumers, and resulting in a large negative economic effect on the beef industry[2].

Dark cutting is an old and well understood meat color phenomenon. Most researchers believed the formation of the dark color was related with meat reflectance and absorbance properties. Compared with normal pH meat, the high ultimate pH beef with net charge of the proteins above the isoelectric point, results in relatively little denaturation of proteins and more associated water, and the differences in refractive index of the myofibrils and sarcoplasm are reduced. The muscle surface does not scatter light to the same extent as the normal pH meat, that making the meat appear darker[3-5]. According to the theory, the pre-rigor muscle with even higher pH will have more net charge and will hold more water around proteins. Thus, pre-rigor meat will scatter less and absorb more light than DFD meat. It follows that the pre-rigor muscle would have an even darker color than DFD meat. To verify this hypothesis, it is necessary to investigate the beef color development within 24h postmortem, which is exactly the time that the ultimate pH is determined, while most of previous studies have focused on the color comparison between DFD and normal pH meat at 24h postmortem or during extended aging time.

Thus, the objective of this study is to investigate the color CIE *L**, *a**, *b**, *C** and *h** of fresh beef with three types of ultimate pH values (5.40-5.80, 5.80-6.10 and great than 6.10) at postmortem times of 45min, 3h, 6h, 12h and 24h, both before and after bloom development in air. The results obtained from this study will provide basic information for further study on color

formation mechanisms of DFD beef.

II. MATERIALS AND METHODS

For the study, 90 Chinese crossbred yellow cattle were randomly selected from one local beef cattle abattoir. Left sides of each carcass were cut between the 12th and 13th rib at 45min postmortem and one steak (2cm thick) was excised immediately, then the steaks were removed at 3h, 6h, 12h and 24h postmortem, from the cranial to caudal. Meanwhile, temperature and pH values were measured on the right sides of the carcass at three positions from cranial to caudal again, for each time point. Samples were grouped based on the pH values at 24h postmortem. Carcasses with 5.40<pH≦5.80 were classified as low ultimate pH group (LpHu), and those with 5.80<pH≦6.10 and pH>6.10 were grouped as intermediate ultimate pH (IpHu) and high ultimate pH groups (HpHu), respectively. All the samples were obtained at 6 separate days; one sample for one pHu group were selected from each experimental day, thus, six carcasses of each pHu group were used for the data analysis.

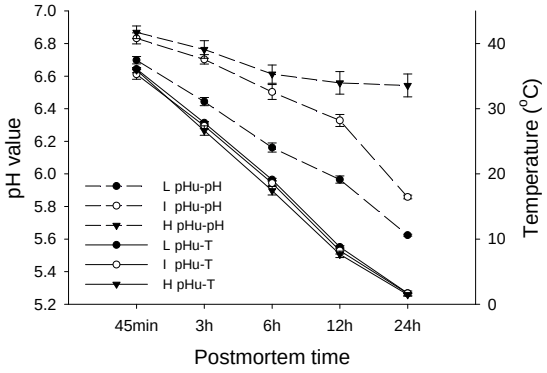
Carcass temperature and pH were measured at 45min, 3h, 6h, 12h and 24h postmortem on the right side of the carcass, using a digital thermometer and a portable pH meter.

The surface color of each beef steak was measured with using a X-Rite spectrophotometer (Model SP62). *L**, *a** and *b** values were recorded. CIE *C** (chroma) and *h** (hue) was also calculated: Chroma = $(a^{*2} + b^{*2})^{1/2}$, Hue = arc tan (*b**/*a**). At least six scans were taken per steak immediately on the fresh cut after the steak was removed. Then another six scans were taken after the samples were exposed in the air for 20 mins (bloom development).

Statistical analysis was carried out with the Statistical Analysis System. Experiments adopted a split-split-plot design. For the whole plot, sampling day served as a block (6). Ultimate pH [5.40≦pH<5.80 (n=6), 5.80≦pH<6.10 (n=6) and pH≥6.10 (n=6)] were assigned to the whole plots within each block. Within the subplot, steaks from each cattle were assigned to 5 postmortem times (45 min, 3h, 6h, 12h and 24h). Bloom time(0, 20 min) were assigned to each split-split plot. The MIXED procedure was used with pHu group, postmortem time, bloom time, and their interactions as fixed factors, and blocks as random factor. Least squares means, generated for the fixed effects and their interaction using the PDIFF statement and differences were considered significantly different at $P < 0.05$.

III. RESULTS AND DISCUSSION

Fig 1. pH and temperature of beef carcasses with different ultimate pH values during early postmortem time



Notes: L pHu (low pHu) represents ultimate pH values: 5.40 ≦ pH<5.80; I pHu (intermediate pHu) represents ultimate pH values: 5.80 ≦ pH<6.10; H pHu (high pHu) represents ultimate pH values: pH≥6.10 (The same as the following table and figs)

While temperatures of the three pHu groups declined at similar rates, the pH decline was significantly different between groups (Fig. 1). Carcass pH values from the three pHu groups all declined significantly within 24h postmortem. The values of normal beef decreased from 6.70 to 5.62, while the pH of DFD beef decreased only from 6.87 to 6.54. This is consistent with the typical pH decline pattern of DFD and normal meat as reported before [3].

Table 1 shows the sources of variation for color CIE *L**, *a**, *b**, *C** and *h** in the

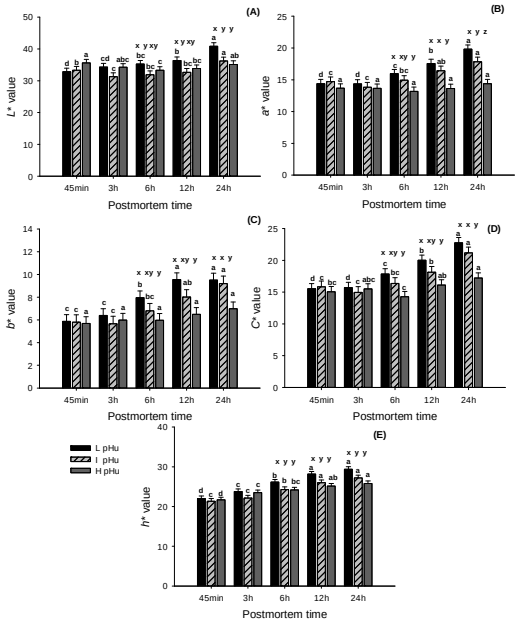
pooled data via the MIX procedure. pHu, postmortem time, blooming and the interaction between pHu and postmortem time all had significant ($P < 0.05$) effects on *a**, *b**, *C* *and *h**; while *L** was only affected by postmortem time and its interaction with pHu.

Sources of variation	*L**	*a**	*b**	*C**	*h**
A=pHu group	ns	***	**	***	**
B=Postmortem time	***	***	***	***	***
C = bloom	ns	***	***	***	***
A*B	***	***	***	***	***
A*C	ns	*	**	***	ns
B*C	ns	*	***	**	**
A*B *C	ns	ns	ns	ns	ns

Table 1 Sources of variation for *L**, *a**, *b**, *C**, *h**

Notes: *** $P < 0.001$;** $P < 0.01$; * $P < 0.05$; $P > 0.05$

Fig. 2 CIE *L**, *a**, *b**, *C** and *h* of beef with different pHu values during early postmortem time (before blooming)

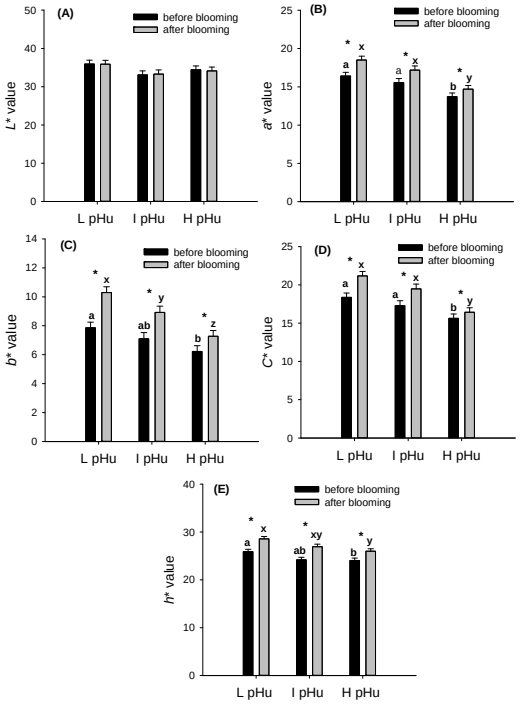


Notes: Means with different superscript letters (a-d)within the same pHu group differ at $P < 0.05$; Means with different superscript letters (x-z) within the same postmortem time differ at $P < 0.05$

All the color parameters for the non-bloomed low and intermediate pHu beef showed an upward trend as postmortem time extended, while for the high pHu beef only the *hue* increased (Fig. 2). And low pHu beef showed a greater *a**, *b**, *C* *and *h** value during 6h-24h compared with that in the first 3h.

After blooming for 20mins, except for *L** value, all the color parameters increased significantly for all pHu type beef (Fig. 3). Low pHu beef had a larger change in color values after blooming, followed by intermediate pHu and high pHu beef. It indicated high pHu beef also had color changes during 20 min bloom time, but a lower bloom capacity.

Fig. 3 Main effect of blooming on CIE *L**, *a**, *b**, *C** and *h* of beef with different pHu values during early postmortem time



Notes: Values with different superscript letters (a-b, or x-z) means differ at $P < 0.05$ between pHu groups before or after blooming, respectively; * means the effect of blooming were significantly within the pHu group at $P < 0.05$.

The bloom color of samples from the three

pH groups during 24h postmortem was not shown. Similarly, but more obviously than non-bloomed samples, *a**, *b**, *C* *and *h** of both low and intermediate ultimate pH increased as postmortem time extended. For high pHu beef,most of the parameters remained at the same level during the first 12h postmortem, and showed a significant increase at 24h postmortem time.

The main effect of postmortem time on color was not shown here. Hue values changed constinuously during the entire postmortem time (24h), while *b**, *a** and *C** changed from 6th and 12th h, respectively. And *L** showed the greatest change after 24h. When considering whole-plot main effect of pHu on beef color, we found that CIE *a**, *b**, *C** and *h** values of high pHu beef was significantly lower than that of the normal pHu group (data not shown). CIE values of intermediate pHu beef were between those of low and high pHu beef. Unexpectedly, *L** values were not shown a significantly different among different pHu groups.

It is seldom to find the beef color information in the literature during the early postmortem period, as the color is unstable with the ongoing rigor. But it is uncertain whether there is a change of the color as postmortem time is extended. In the present study, continuous color changes were found within 24h postmortem, and the extent of color alteration increased as ultimate pH decreased. An alternate explanation involves pH changes in oxygen consumption[1].

Referring to the pH, in this study, the ultimate pH of dark cutting beef was a little lower than the initial pH of low ultimate pH beef, then, a color comparison between 24h-DFD beef and 45min-normal pH beef was taken. Results showed that no significant difference of *L**, *a**, *b**, *C** values was found between two groups, while *h** of 24h-dark cutting beef was significantly higher than that of 45min-normal pH beef, both before and after blooming (P = 0.043 and 0.024, respectively). The results obtained are not consistent with our "pre-rigor muscle would be darker" hypothesis. *h** is one of the main color properties, in the term for the pure spectrum rainbow colors, usually referred to "red, orange, yellow, blue, green and violet", while it does not take lightness (white and black) into the consideration. This suggests that the color differences of the two types of dark beef (DFD or normal pre-rigor) is not associated with lightness and darkness. Further study is require to investigate the physicochemical and metabolic differences between DFD beef and pre-rigor muscles, which would give a new insight into the underlying mechanisms of dark color development.

IV. CONCLUSION

This is the first report that beef color changes continuously during early postmortem time. While the extent of color alteration was different among samples with differing ultimate pH, color parameters usually decreased as ultimate pH increased. High ultimate pH, also called dark cutting beef, changed color most noticeably during 12 to 24 h postmortem. We also found the *L** is not a good indicator of different ultimate pH beef groups; *h** is a better candidate. Also, *h** can be used to distinguish between pre-rigor muscle and DFD beef. Further study is warranted to investigate the underlying mechanism(s) of color development of dark cutting beef.

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