POTENTIAL MECHANISMS OF COLOR IMPROVEMENT FOR DARK CUTTING BEEF DERIVED FROM CARBON MONOXIDE PACKAGING AND HIGH OXYGEN PACKAGING ARE DIFFERENT

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Abstract – It has been found that carbon monoxide (CO) modified atmosphere packaging (MAP) improves the colour of dark cutting beef as does high oxygen (HiOx) MAP. However the underlying mechanisms which operate in both cases has not been explored. Therefore, in this study, relative contents of metmyoglobin (MetMb), MRA (metMb reducing activity), and thickness of the bright red layer were determined for dark cutting beef (ultimate pH (pHu) ≥ 6.10), compared with normal pHu beef and intermediate pHu beef (pH: 5.40-5.79; pH: 5.80-6.09, respectively) under CO-MAP and HiOx-MAP stored for up to 20d at 2°C. The MetMb content was lower under CO-MAP than under HiOx-MAP in normal pHu beef, but opposite effects were observed in dark, high pH beef. This result was not explained by MRA, as this parameter was higher in CO-MAP beef than either normal or high pHu beef, compared with HiOx-MAP. The cherry red surface layer of dark cutting beef became progressively thicker as storage time increased under CO-MAP, while the layer was relatively stable under HiOx-MAP. The results suggest the mechanism for the color improvement of dark-cutting beef is different between HiOx-MAP and CO-MAP packaging methods.

Key Words –CO-MAP, MRA, MetMb.

I. INTRODUCTION

CO modified atmosphere packaging (MAP) can be used in a number of countries and has been applied to improve beef color [1]. Under a CO atmosphere, CO can bind to the sixth coordinate position of the heme iron group, which is centrally located within myoglobin, and the resultant carboxymyoglobin (CO-Mb) has a very bright cherry-red color. The binding force of CO to Mb is much more powerful than O_2, so that CO-Mb is much more stable than oxymyoglobin (OxyMb) [1]. Very recently, it was found that CO-MAP produced a similar color improvement of L^* and a^* values (unpublished data) for dark-cutting beef, compared with HiOx-MAP. However, the redness increased after 4 days of storage under CO and was much greater than vacuum packed meat irrespective of pH and by 20 days was redder than meat stored under HiOx. This suggested that the color improvement for dark cutting beef under the two packaging methods might be different. Therefore, in this study, several color chemical parameters were measured to determine whether the Mb oxidation and reduction status of dark-cutting beef are different under the two packaging atmospheres.

II. MATERIALS AND METHODS

Chinese crossbred yellow cattle (Luxi × Simmental, 18-24 months of age) carcasses with normal ultimate pH (pHu, 5.40-5.79, n=4), along with four carcasses with intermediate pHu (5.80-6.09) and four with high pHu (≥ 6.10) were randomly selected on the slaughter line after grading (24h postmortem) at a beef abattoir. The *M. longissimus lumborum* were removed from both sides, vacuum packaged and transferred to the lab within 2h. Each muscle was then portioned into 2cm beef steaks, and randomly assigned to: Vacuum packaging, HiOx-MAP (80% O_2, 20% CO_2) or CO-MAP (0.4% CO, 30% CO_2, 69.6% N_2). The packaging material was the same as that applied in a previous study [2], and all the steaks for each pHu group were stored at 2°C for 20d. Three steaks per carcass of each pHu group remained unpackaged and were prepared for day 0 samples (initial color, blooming for 30 min). Eight steaks from each packaging and each pHu group were randomly selected and were measured for color, reflectance, MRA, and thickness of red layer at 4d, 8d, 14d and 20d of storage [2]. The MIXED procedure (SAS,Version 9.0) was used with pHu group, storage time, packaging, and their interactions fitted as fixed effects, and animal with three pHu as a random effect. Tests of differences between predicted means were applied using the PDIFF statement and differences were considered significantly different at $P < 0.05$.

III. RESULTS AND DISCUSSION

There is no significant difference for initial MetMb content among different pHu groups (Table 1). As storage time extended, the MetMb content of vacuum packaged beef did not change markedly. The effect of packaging

atmosphere on the MetMb level varied by pHu groups. For normal pHu meat, HiOx resulted in a significant increase in MetMb content with the prolongation of the storage, which was also found previously [2]. This is partially because of the decreased MRA when beef was exposed into high oxygen atmosphere, and less MetMb could be reduced back to DeoxyMb. But, for intermediate pHu and high pHu beef packed under HiOx-MAP, the MetMb content changed less than normal pHu beef, which was the result from their significantly ($P < 0.05$) higher MRA than the normal pHu beef (Table 2). Interestingly, MetMb content of CO-MAP steaks increased from 4d storage, and kept a relatively stable level during storage, regardless of meat pH. MetMb level was lower than those under HiOx-MAP, but higher than vacuum packaging for normal pHu beef. Also, CO-MAP resulted in a higher content of MetMb for dark cutting beef than for the other two packaging methods. This might be related with a very small amount of residual oxygen in the CO-MAP. However, the MRA is higher in CO-MAP than that in HiOx. Additionally, we also found the cherry red surface layer of dark cutting beef was progressively thicker (from 2.65mm to 6.93mm) as storage time increased in CO-MAP, while the layer was relatively stable (5.61mm to 5.99 mm) within HiOx-MAP.

Table 1 Effect of packaging and storage time on the surface content of MetMb(%) of beef steaks with normal, intermediate or high pHu (5.40-5.79; 5.80-6.09; ≥ 6.10) stored at 2°C

pH	Package	Storage time (day)					
		0	4	8	14	20	SE
Low pHu	Vacuum	4.0aix	4.5aiz	4.83aiz	5.1aiy	6.4aiy	
	HiOx	4.0dix	16.0cix	20.9bix	23.4abix	25.6aix	
	CO-MAP	4.0bix	9.6ajy	12.7aiy	9.6aijy	9.4ajy	
Intermediate	Vacuum	1.5aix	1.3aiy	3.4aiy	5.2aix	4.9aiy	
pHu	HiOx	1.5bix	4.0bjy	8.2abjx	8.8ajx	12.6ajx	0.8
	CO-MAP	1.5bix	11.6aijx	10.0aix	8.4ajx	9.1ajxy	
High pHu	Vacuum	2.2aix	1.7aiy	6.1aiy	3.9aiy	5.3aiy	
	HiOx	2.2bix	5.5abjy	7.2ajy	6.9ajy	6.2abky	
	CO-MAP	2.2bix	14.aix	12.1aix	13.4aix	16.5aix	

Notes: Means with different superscript letters (a-b) within the same row differ at $P < 0.05$; (i-k) within the same packaging group differ at $P < 0.05$; (x-z) within the same pHu group differ at $P < 0.05$.

Table 2 Effect of packaging and storage time on the metmyoglobin reducing activity of beef steaks with normal, intermediate or high pHu (5.40-5.79; 5.80-6.09; ≥ 6.10) stored at 2°C.

MRA		Storage time (day)					
		0	4	8	14	20	SE
Low pHu	Vacuum	64.8abjx	61.5abjx	67.3aix	64.0abix	58.4bjx	
	HiOx	64.8ajx	28.2cjy	38.7bjy	6.7djy	7.7djy	
	CO-MAP	64.8ajx	66.2aix	63.7aix	63.5aix	58.6ajx	
Intermediate	Vacuum	71.0ajx	74.0aix	72.4aix	69.8aix	70.0aix	
pHu	HiOx	71.0ajx	62.0biy	52.0ciy	58.3bciy	51.8ciy	1.6
	CO-MAP	71.0ajx	71.2aix	69.5abix	65.3abixy	61.9bijx	
High pHu	Vacuum	79.6aix	75.8abix	71.3bix	71.3bix	72.1abix	
	HiOx	79.6aix	66.5biy	53.9ciy	51.4ciy	50.7ciy	
	CO-MAP	79.6aix	72.6abixy	70.2bix	67.9bix	67.6bix	

Notes: The same as the above.

IV. CONCLUSIONS

We found dark-cutting beef under CO-MAP exhibited higher MRA and less oxidative level than HiOx-MAP. Specificly, CO-MAP resulted in a higher surface MetMb percentage than HiOx-MAP, which indicates that the relationship between MRA and MetMb content in CO-MAP was different with HiOx-MAP. Further study is warranted to investigate more underlying mechanism(s) of color development of dark cutting beef under CO atmosphere.

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