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USE OF HIGH PRESSURE FOR APPLICATION OF CARBON MONOXIDE IN CASE-READY PACKAGING SYSTEMS FOR FRESH BEEF

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Introduction

The color of fresh beef is a primary determinant of quality to the retail consumer. Kropf (1980) suggested that the single greatest factor determining the purchase of meat at retail was probably muscle color.

Several researchers have shown that the addition of carbon monoxide (CO) to fresh beef can improve and stabilize the bright red color associated with high quality fresh beef (Hunt et al., 2004; Jayasingh et al., 2001; Luno et al., 2000). These researchers have tested the use of CO at low concentrations (0.1 to 5.0%) in a modified atmosphere package (MAP) to stabilize beef color, delay metmyoglobin formation, and extend retail case life. Jayasingh et al. (2001) found that beef needed 24 h in a 5% CO atmosphere in order to stabilize the bright red color when repackaged in a vacuum package. Reducing the CO application time is necessary for high speed case-ready packaging systems because a CO application time of 24 h is not feasible in a high volume situation. Reducing the CO application time to seconds rather than hours would allow for case-ready packages with meat-to-film contact, such as vacuum packaging, which may be more appealing to consumers than MAP packages with 'head space' between the meat surface and film. It may be that 100% CO applied under high pressure could accomplish beef bright red color fixation in relatively short application times.

Objectives

Hypothesis: High pressure can be used for the application of carbon monoxide (CO) to fresh beef to minimize the time required for color fixation in a high speed case-ready packaging system.

Objective: Determine if high pressure could be used for the application of carbon monoxide (CO) to fresh beef in order to minimize the time required for color fixation in a high speed case-ready packaging system.

Methodology

Beef steaks were cut from USDA Select subprimals, and 100% CO gas was applied to each steak using high pressure chambers. Initial CO penetration was measured by

cutting a cross section of each steak immediately following CO application. Steaks were then immediately packaged in anaerobic MAP packages with a mixture of nitrogen and carbon dioxide. The MAP packages utilized shallow trays which resulted in meat-to-film contact (no head space in packages). On d1 following CO application and packaging, a* was measured on the surface of each steak using a Minolta colorimeter Model CR-310 and a D65 illuminant. Our preliminary research showed that d1 a* was highly correlated with subsequent a* readings (d2 to d20) during retail display for CO-treated steaks packaged in anaerobic MAP with meat-to-film contact (Figure 1). Therefore, we report d-1 a* in this paper because d-1 a* is an indicator of beef color across all days of retail display in CO-treated fresh beef in anaerobic packages.

Phase 1 – Effect of pressure and duration.

In Phase 1, 32 beef steaks were cut from longissimus muscle (LM) and used in a 2 x 3 factorial treatment design with two pressures (1724 and 3447 kPa) and three durations (30, 60, and 90 sec).

Phase 2 – Effect of duration and muscle using enhanced steaks.

In Phase 2, 109 beef steaks, enhanced to 110% of green weight with a solution of water, phosphate and salt, were used and CO was applied at 3447 kPa using a 3 x 3 factorial treatment design with three muscles (LM, psoas major = PM, semimembranosus = SM) and three durations (15, 22.5 and 30 sec).

Results & Discussion

Phase 1 – Effect of pressure and duration.

Steaks treated at 3447 kPa had greater initial CO penetration than steaks treated at 1724 kPa (Table 1). Steaks treated for 60 or 90 sec had greater initial CO penetration than steaks treated for 30 sec. Therefore, CO penetration was a function of both pressure and duration of CO application. Steaks treated at 3447 kPa had higher d-1 a* than steaks treated at 1724 kPa (Table 2). Duration had no effect on d-1 a* ($P > 0.05$). Through case life monitoring in preliminary studies, we had determined that a minimum of approximately 1.00 mm of initial CO penetration and a minimum d-1 a* of 25 to 27 were required for color stability in an anaerobic package. Given these minimums, it appeared from Phase 1 that color stability could be accomplished with either a 60-sec duration at 1724 kPa or a 30-sec duration at 3447 kPa (Table 1 and 2). We wondered if color stability could be accomplished at 3447 kPa in less than 30 sec; hence, shorter durations were tested in Phase 2.

Phase 2 – Effect of duration and muscle using enhanced steaks.

As duration of CO application increased from 15 sec to 22.5 sec to 30 sec, initial CO penetration increased (Table 3). Steaks from SM had a greater initial CO penetration than steaks from PM which had a greater initial CO penetration than LM. As duration of

CO application increased from 15 sec to 22.5 sec to 30 sec, d-1 a* increased (Table 4). Day-1 a* was highest for PM steaks, intermediate for LM steaks and the deep side of SM steaks, and lowest for the superficial side of SM steaks. Carbon monoxide penetration was deepest for SM steaks, but SM steaks were less red than the other muscles. Steaks from SM may require a deeper CO penetration than other muscles. Assuming a minimum d-1 a* of 25 to 27, CO application at 3447 kPa would require a minimum application duration of 30 sec for LM and SM steaks and a minimum application duration of 15 to 22.5 sec for PM steaks. These durations required for color fixation are considerably less than those required when CO is used in low concentrations in MAP packaging (Jayasingh et al., 2001).

Conclusions

High pressure (3447 kPa) application of CO was effective at fixing fresh beef color in 30 sec or less for application in anaerobic MAP systems. This short duration required for color fixation when using high pressure CO application may make it feasible to use in a high speed, high volume case-ready operation. Stabilizing color with CO would allow for retail beef to be sold with bright red color while using vacuum packaging or anaerobic MAP with meat-to-film contact.

References

Hunt M.C., Mancini R.A., Hachmeister K.A., Kropf D.H., Merriman M., DelDuca G., and Milliken G. 2004. Carbon monoxide in modified atmosphere packaging effects color, shelf life, and microorganisms of beef steaks and ground beef. J. Food Sci. 69:45–52.

Jayasingh P., Cornforth D.P., Carpenter C.E., and Whittier, D. 2001. Evaluation of carbon monoxide treatment in modified atmosphere packaging or vacuum packaging to increase color stability of fresh beef. Meat Sci. 59:317–324.

Kropf D.H. 1980. Effects of retail display conditions on meat color. Proc. 33rd Recip. Meat Conf., West Lafayette, Indiana. pp 15–32.

Luno M., Roncales P., Djenane D., and Beltran J.A. 2000. Beef shelf life in low O2 and high O2 atmospheres containing different low CO concentrations. Meat Sci. 55:413–419.

Tables and Figures

Figure 1. Effect of d-1 a* readings of CO-treated beef longissimus steaks packaged in anaerobic MAP with meat-to-film contact on subsequent a* readings during d 2 to 20 of retail display.

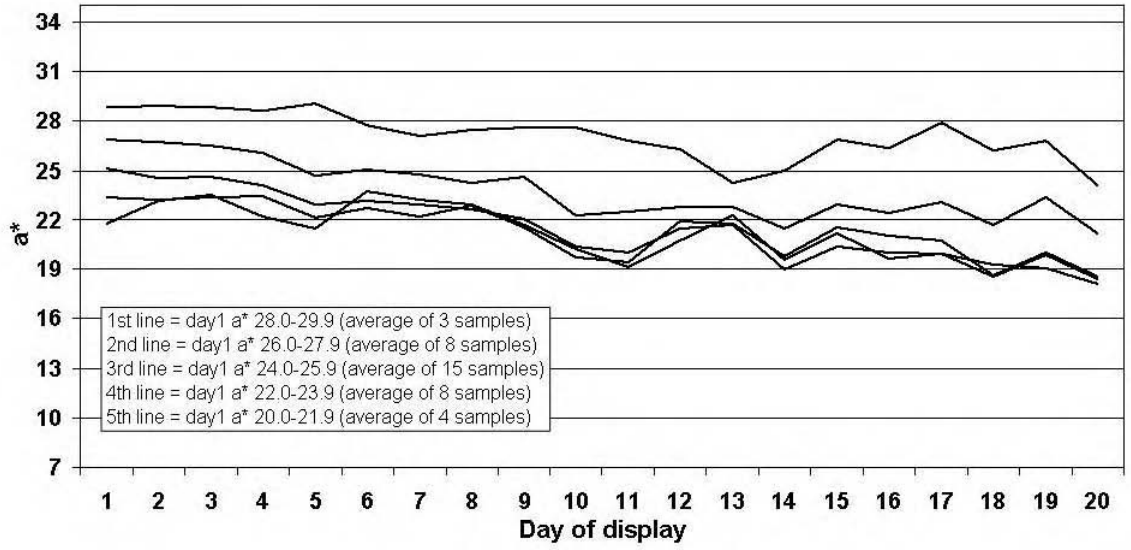

Table 1. Effects of pressure and duration of CO on initial color penetration (mm) in non-enhanced beef longissimus steaks (pressure P = 0.0476, duration P = 0.0001, pressure x duration P = 0.3796; means lacking a common letter differ, P < 0.05).

	Pressure		
Application duration	1724 kPa	3447 kPa	Average
30 sec	0.76	0.95	0.86a
60 sec	1.07	1.27	1.17b
90 sec	1.27	1.27	1.27b
Average	1.03a	1.16b	

Table 2. Effects of pressure and duration of CO on d-1 a* in non-enhanced beef longissimus steaks (pressure P = 0.0477, duration P = 0.1448, pressure x duration P = 0.4848; means lacking a common letter differ, P < 0.05).

	Pressure		
Application duration	1724 kPa	3447 kPa	Average
30 sec	23.2	27.7	25.4
60 sec	27.3	28.5	27.9
90 sec	27.2	29.0	28.0
Average	25.9a	28.4b	

Table 3. Effects of muscle and duration of CO application at 3447 kPa on initial color penetration (mm) in enhanced beef steaks (muscle P = 0.0001, duration P = 0.0172, muscle x duration P = .8480; means lacking a common letter differ, P < 0.05).

Application duration	Pressure			
	Longissimus	Psoas major	Semimembranosus	Average
15.0 sec	0.84	0.95	1.34	0.88a
22.5 sec	0.78	1.12	1.52	1.10b
30.0 sec	1.02	1.24	1.78	1.39c
Average	1.05a	1.14b	1.52c	

Table 4. Effects of muscle and duration of CO application at 3447 kPa on d-1 a* in enhanced beef steaks (muscle P = 0.0001, duration P = 0.0001, muscle x duration P = 0.0733; means lacking a common letter differ, P < 0.05).

Application duration	Pressure				
	Longissimus	Psoas major	Semimem-branosus (superficial)	Semimem-branosus (deep)	Average
15.0 sec	23.9	25.3	20.9	22.3	23.1a
22.5 sec	24.8	28.7	21.1	24.5	24.8b
30.0 sec	25.5	29.1	25.4	26.6	26.6c
Average	24.8b	27.7c	22.5a	24.5b	