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COLOR STABILITY OF CHILLED BEEF PACKAGED IN AN ATMOSPHERE CONTAINING LOW LEVEL OF CARBON MONOXIDE

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Introduction

The main purpose of MAP of chilled meat is to extend the microbiological shelf life and the color stability of the packaged meat. The gas composition normally used in MAP is 70%O_2/30%CO_2 or 60% 70% CO_2/30% 40%N_2. The 70%O_2/30%CO_2 gives the product an extended shelf life compared to air Gill,1996 .Although the elevated concentration of oxygen prolong color stability of the meat, it is also expected to increase the rate of lipid oxidation (zhao, et al 1994) which causes a rancid off-flavor in meat. The 60% 70% CO_2/30% 40%N_2 further extend the shelf life of packaged meat, but because of the non-oxygen atmosphere and elevated CO_2 concentration, the meat become dark pink or pale brown after packaging. CO is a colorless, odorless and tasteless gas, which can binds strongly to the meat pigment myoglobin to form stable ,cherry red carboxymyoglobin. The technological, hygienic and toxicological aspects of using CO in MAP for meat have recently reviewed with the conclusion that CO used in concentrations up to 1% does not present a toxic hazard to the consumer (Sorheim,Aune and Nesbakken,1997). To obtain a stable red color for the meat while prevent the meat lipid from oxidizing, low concentrations of CO can be introduced into the package which contain no oxygen.

Objectives

The objective of present study was to compare different MAP (with and/or without CO) and vacuum packaging on the shelf life and the color stability of chilled beef, and eventually to obtain 21 days shelf life and red color stability for beef packaged in low level carbon monoxide without the application of oxygen.

Methodology

Gas composition

The original gas mixtures were designed as 0.5%CO/60%CO_2/39.5%N_2 70%O_2/ 30%CO_2 and 60%CO_2/40%N_2. The actual gas mixtures used in the study were supplied by Beijing Haipu Gas company and consisted of 0.5%CO/60.4%CO_2/39.1%N_2 (referred to as CO group), 69.9%O_2/30.1%CO_2 (referred to as HO group) and 62.8%CO_2/37.2%N_2 (referred to as NO group). And the vacuum packaged group referred to as VA group.

Samples preparation

Beef *Longissimus dorsi* muscle which had aged at 1±1 for 48 hours were used. Before packaging, the muscles were trimmed of external fat and cut into 1.5 cm thick steaks of about 100g and randomly grouped into 4 groups, each has 18 samples. To limited the discoloration caused by bacteria, all the hands, instruments and knifes were sterilized using 75% ethanol before the cutting.

Packaging parameters and storage conditions

One group of sample steaks were vacuum packaged in polyethylene bags using Multivac machine (Wolferschwenden,Germany) , and the other three groups of sample steaks were placed on polystyrene tray of size 18×24×3cm with the top film made of polyethylene and polyamide laminated(water vapor permeability 8g/m^2·24h at 23 ,oxygen permeability 40-50ml/m^2·24h at 23) .Then the trays were flushed with selected gas mixtures(HO, CO, NO) using MAP machine(Ross Industry Inc), respectively. Immediately after packaging, the samples were kept at 1±1 until sampled.

Sampling

Three samples were collected from each group at an interval of 7 days for measurements of redness a* value, MMb% ,TBA values and sensory panel evaluations.

MMb%

MMb% of the samples were measured by HITACHI 557 Reflectance Spectrophotometry according to Judd (1975).

TBA

Lipid oxidation was measured using the 4 mm top layer of each sample, homogenized with a kitchen blender. The lipid oxidation was estimated as TBARS by the extraction method of Witte(1970)

Color

Color was measured on the meat surface immediately after opening the package using a TC-P G-Colormeter (Beijing optical instrument Co.) and expressed as CIE a* value (redness).

Meat samples were evaluated by a seven-member expert panel. The attributes studied were: Red color, Discoloration and Fresh meat odor. All three attributes were scored using a 5-point scale. For “Red color”, 5 denoted extremely high and 1 denoted extremely low. Scores for “Discoloration” referred to percentage of discolored surface, according to

Luno(2000):1=none, 2=0-10%, 3=11-20%,4=21-60%,and 5=61-100%. Scores for "Fresh meat odor" were:1=excellent,, not different from fresh meat; 2=good, but slightly poorer than fresh meat; 3=acceptable, but obviously poorer than fresh meat; 4=hardly acceptable as fresh meat; and 5=non acceptable. Samples were scored by each panel member, and mean values were agreed there of after discussion by all seven panelists.

Statistical analysis

Analysis of variance by Tukey's multiple comparisons test was performed using SPSS software (Version8.0).Significance was defined at $p<0.05$.

Results & Discussion

The color changes during storage

As showing in Fig.1, during the first week of storage, the color of samples in the HO group were bright red, but these samples began to discolor during the second week and at the 14^{th} day of storage, MMb% exceed 50% and at the 35^{th} day of storage, the sample were totally discolored. The result indicated: the high level of oxygen(69.9%O_2) in the HO group can cause lipid oxidation during storage, the free radicals produced from lipid oxidation accelerated the formation of metmyoglobin, which give the meat brown color. The color of samples in VA group were remain dark red during the entire 4-week study. The color of samples in the NO group became pale immediately after packaging, the redness a* value consistently lower than that of the VA group $p<0.05$; The color of samples in the CO group kept bright red and the redness a* value maintained very high through the entire 4-week study.

In the vacuum package where the oxygen was totally depleted, the meat pigment maintain in the reduced form, thus give the meat dark red color during the entire 4-week study. In the NO group, because of the high concentration of CO_2, which can dissolve in the meat and lower the pH value of the meat surface, give meat a pale color, and the redness a* value of NO group lower than the VA group through the entire 4-week study $p<0.05$ .The introduce of low level of carbon monoxide to the package made the CO group maintained bright red through the entire 4-week study.

The changes of MMb% in the surface of the chilled beef presented in fig.2.At the end of the study, the difference of the redness a* value of the four different groups were significant($p<0.01$),the order of the redness a* value from high to low were CO VA NO HO. Because there is a high corelationship between redness a* value and MMb%, so the higher the redness a* value, the lower the MMb%.

The lipid oxidation during storage

As showing in the Fig.3, during the 35 days of storage, the TBA value of samples in the CO, NO and VA group maintain very low, and at the 35^{th} day of storage, all the three groups had TBA values lower than 0.5mg/kg. The TBA value of HO group increased slowly in the first 2 weeks, from 14^{th} days of storage, it increased quickly and at 21^{st} days, the rate of the increase was slow down. During the 4-week study, the TBA value of

HO group increased from 0.37 to 4.93, the variation is significant compared with the other three group $p<0.01$.

The change of the TBA value indicated that high concentration of oxygen can give the chilled beef bright red color ,but the color stability time was limited, only 4 to 6 days. At the same time, the high concentration of the oxygen could increase the lipid oxidation, the radicals produced from the oxidation can increase the discoloration .So HO package only suitable for short shelf-life chilled beef products. For those whose shelf life is expected to be 1 week or more, it was not recommend to use the HO MAP. The result also suggested that the atmosphere of NO, CO and VA group can inhibit lipid oxidation. Besser and Kramer (1972) reported that CO is an enzyme inhibitor and can inhibited lipid oxidation, which can delay the Mb and Hb oxidation. But in our study, because of the low CO concentration, we did not found any significant difference in lipid oxidation in these three groups.

The TVB-N changes during storage

As showing in Fig.4, The TVB-N value of HO group increased very fast after packaging, and at the 14th day of storage, the value has exceed 15mg/kg, which indicate the end of its shelf life. Several studies indicated that most of the micro flora which cause the putrefaction of the meat are aerobic bacteria, in the present of O_2, the bacteria grow very quickly and decomposed protein and other nutrients into peptides, amino acid and other small N-containing organic compounds, that why the TVB-N value of the HO group increased very quickly during the study. The TVB-N value of other three groups increased very slowly at the first three weeks, and then kept relatively stable. There are may be two reasons for this: first ,there were no O_2 in the gas mixtures of VA, NO and CO groups, so the main bacteria survived was LAB, who can produce lactic acid during growth which can lower the pH of the beef. Second, there were high concentration of CO_2 in these three groups, and the solubility of CO_2 in water and in lipid are very high(Gill.C.O1988), which can form carbon acid on the surface of the beef, so the TVB-N value was not increased after 21 days of storage.

The panel scores during storage

The panel scores, including redness, discoloration, fresh flavor were collected during the 4-week study and presented in Table 1.. The samples of HO group maintained bright red for one week ,and then discolored completely; the color of the CO group maintained bright red through out the entire 4-week study; The NO group discolored very quickly in the first week; the VA group maintained dark red during the whole storage period, but the drip losses of the VA group can be as high as 6%,which make the meat less acceptable to consumers.

For the fresh meat flavor, at the 14 day , the sample in the HO group have rancid flavor after cooking, while the samples in the CO,NO,VA group have no off-flavor at this time of storage. At the 21st day storage, the flavor of CO and NO groups began to deteriorate and at 28th days, the flavor deteriorating of VA group is one week later than the CO and NO groups, this indicated that the low concentration of CO has no effect on the flavor change of the packaged beef.

El-Badawi (1966) reported that CO can bond to Mb to form CO-Mb, who has similar light reflectance with MbO_2. Clark(1976), Luno(1998) reported that $1\%CO+25\%N_2+24\%O_2+50\%CO_2$ can keep the bright red color of the beef. Kropf(1980),Sorheim(1997)reported that 0.5-2%CO can keep chilled beef bright red. In our studies, we only applied $0.5\%CO+/60.4\%CO_2+39.1\%N_2$ in the gas mixtures but the color preserve effect is significant. Danity and Mackey (1992) reported that 10%CO can keep beef color, at the same time can inhibited the microbial growth. But in our studies we did not found any bacteria static effect of the CO due to the low concentration of CO in the gas mixture.

Conclusions

Beef stored in $0.5\%CO/60.4\%CO_2/39.1\%N_2$ kept bright red and had TVB-N value lower than 20 mg/100g at 28^{th} days of storage. Beef stored in $70\%O_2/30\%CO_2$ could keep bright red for one week and then the lipid would be oxidized and strong off-odor was produced. Beef packaged in $60\%CO_2/40\%N_2$ or vacuum could keep TVB-N value lower than 20mg/100g at 28^{th} days of storage, but the color would be brown or dark pink and would not be accepted. The studies suggested it was feasible to extend the shelf life and color stability of the chilled beef to 21 days or more by modified atmosphere packaging with gas mixtures of $0.5\%CO/60\%CO_2/39.5\%N_2$.

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Tables and Figures

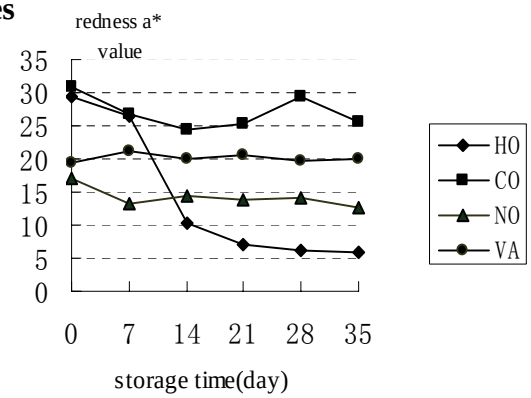

Fig. 1 The redness a* value of chilled beef packaged in different atmosphere during storage at 1±1

Fig2 The MMb% of chilled beef packaged in different atmosphere during storage at 1±1

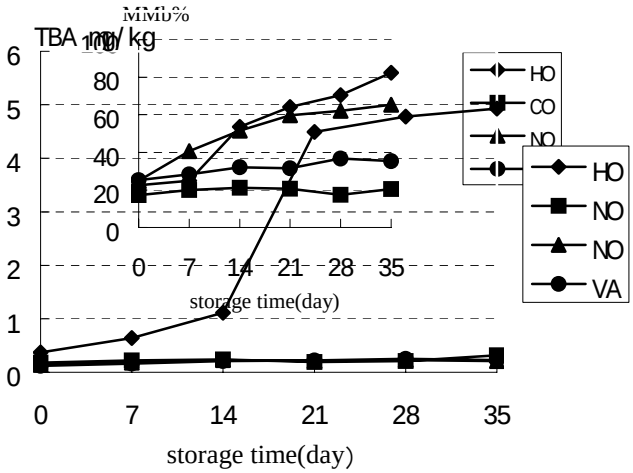

Fig.3 TBA value of chilled beef packaged in different atmosphere during storage at 1±1

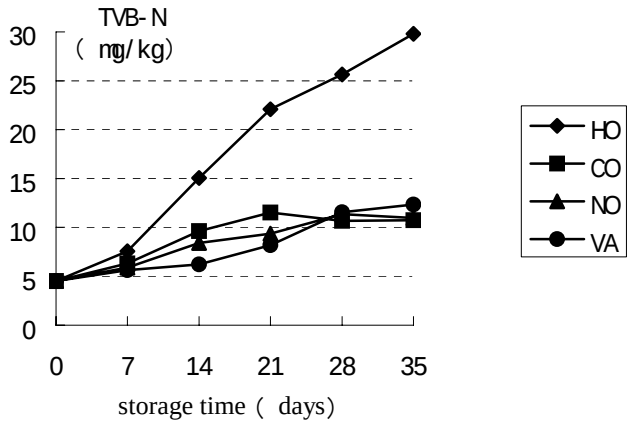

Fig4 The TVB-N value of chilled beef packaged in different atmosphere during storage at 1±1

Table 1 Mean sensory value of chilled beef steak

value	Group	Storage time(day)					
		0	7	14	21	28	35
redness	HO	5	4	2	1		
	CO	5	5	5	5	5	5
	NO	5	3	2	2	1	
	VA	5	4.2	4	4	3.5	3.5
discoloration	HO	1	3	5			
	CO	1	1	1	1	1	2
	NO	1	3	4	4	5	
	VA	1	1	1	1.5	2	2
flavor	HO	1	2	4	5		
	CO	1	1	1	2	3	3
	NO	1	1	1	2	3	3
	VA	1	1	1	1	2	3

“Red color”, 5 denoted extremely high and 1 denoted extremely low.

“Discoloration” 1=none, 2=0-10%, 3=11-20%,4=21-60%,and 5=61-100%.

“Fresh meat odor”:1=excellent,, not different from fresh meat; 2=good, but slightly poorer than fresh meat; 3=acceptable, but obviously poorer than fresh meat; 4=hardly acceptable as fresh meat; and 5=non acceptable.