EFFECTS OF SELF-CARBON DIOXIDE-GENERATION MATERIAL FOR ACTIVE PACKAGING ON MICROBIAL GROWTH IN BEEF DURING COLD STORAGE

Seung J. Lee[1], Seung Y. Lee[1], Hyeong S. Kim[1], Sung Y. Yoon[1], On Y. Kim[1], Da Y. Lee[1], Gap D. Kim[2], Geun B. Kim[1], Sang K. Jin[3] and Sun J. Hur[1,*]

[1] Department of Animal Science and Technology, Chung-Ang University, Gyeonggi, Anseong 456-756, Republic of Korea

[2] Department of Food Science and Biotechnology, Kyungnam University, Gyeongnam, Changwon 631-701, Republic of Korea

[3] Department of Animal Resources Technology·, Gyeongnam National University of Science and Technology, Gyeongnam, Jinju 660-758, Republic of Korea

[*] Corresponding author email: hursj@cau.ac.kr

Abstract – Self-carbon dioxide-generation material was used for active packaging of beef to inhibit microbial growth during storage. Beef loin samples were divided into 3 packaging groups (C: ziplock bag-packaging, T1: vacuum-packaging, T2: active-packaging) and stored at 4°C for 21 days. The thiobarbituric acid reactive substances (TBARS) value was significantly lower in T1 and T2 after 7 days of storage. The counts of total bacteria, lactic acid bacteria, and *Escherichia coli* were significantly lower in T1 and T2 after 7 days of storage; the total bacterial counts and *E. coli* count were lowest in T2 at the end of storage.

Key Words – Beef quality, Lipid oxidation, Microorganisms

I. INTRODUCTION

It has been reported that the quality of meat is strongly affected by the storage conditions or packaging methods of the meat. The packaging methods such as MAP can help maintain meat qualities such as color, the water-holding capacity (WHC), lipid oxidation, and inhibition of the growth of spoilage microorganisms [1]. Korpf reported that CO_2 inhibits gram-negative aerobes than do other microbes [2]. The effects of active packaging on the quality characteristics have not been extensively studied in beef during storage. We developed a novel concept and materials for MAP known as active packaging using self-CO_2-generation materials, ethanol-generation materials, or O_2 scavengers. Thus, the aim of this study was to determine the effect of active packaging by using self-CO_2-generation materials on the shelf-life of beef during cold storage.

II. MATERIALS AND METHODS

A. Sample preparations

After packaging, the meat samples were stored at 4°C and analyzed after 1, 7, 14, and 21 days of storage.

B. Lipid oxidation

TBARS value as a lipid oxidation value was determined by the method of with a slight modification [3].

C. Microorganisms

The microbial counts were determined by the total plate count (TPC) method and the number of lactic acid bacteria and *Escherichia coli* counts were determined as per the standard procedures [4].

D. Statistical analysis

The Student–Newman–Keuls multiple range test was used to compare the differences between the means. Significant difference ($P < 0.05$) between the mean values of quintuplicate samples was determined for microbial counts.

III. RESULTS AND DISCUSSION

The results of the effect of active packaging on TBARS and the microbial counts in beef are presented in Table 1 and 2. The influence of active packaging on TBARS (as a lipid oxidation value) in beef is presented in Table 1. The TBARS value

Table 1 The effects of active packaging on the TBARS in beef during cold storage

	Treatments		
Storage (days)	C	T1	T2
1	$0.32^{d2)}$±0.08	0.35^{c} ± 0.05	0.34^{d} ± 0.07
7	0.63^{Ac}±0.04	0.52^{Bb} ± 0.05	0.49^{Bc} ± 0.07
14	0.75^{Ab}±0.05	0.66^{Bab} ± 0.04	0.59^{Cb} ± 0.03
21	0.97^{Aa} ± 0.08	0.74^{Ba} ± 0.02	0.67^{Ba} ± 0.05

C: Ziplock bag packaging, T1: vacuum packaging, and T2: active packaging, MA, malondialdehyde.
$^{A, B}$ Means ± SD with different superscripts in the same column differ significantly at $p<0.05$. $^{a, b, c, d}$ Means ± SD with different superscripts in the same row differ significantly at $p<0.05$.

increased significantly during the storage period in all samples. The TBARS value was significantly lower in the T1 and T2 samples than in the C sample after 7 days of storage, probably due to the lower O_2 content in the vacuum-packaged meat and higher CO_2 contents in the active-packaged meat than those in the ziplock bag-packaged meat. Numerous studies have reported that the presence of CO_2 and vacuum-packaging conditions result in less lipid oxidation than that in aerobic-packaging conditions [5]. Thus, we believe that the active-packaging method can improve the shelf-life and consumer acceptance of beef with less lipid concentration during cold storage.

The influence of active-packaging methods on the growth of microorganisms in beef is presented in Table 2. The number of microorganisms increased with cold storage in all samples. The total bacterial, lactic acid bacteria, and *E. coli* counts were significantly lower in the T1 and T2 samples than in the C sample after 7 days of storage. In particular, the total bacterial counts and *E. coli* count were lowest in the T2 sample than in the other samples at the end of the storage period (i.e., 21 days). A high CO_2 level (10–80%) is desirable for the storage of foods such as meat and poultry as it facilitates inhibition of surface microbial growth and extends the shelf-life of the food [6]. The results of this study showed that all bacterial growth was delayed by the self-CO_2-generation materials in the T2 sample. These findings indicate that CO_2 was the most effective antimicrobial factor and that the total bacterial growth can be decreased by active packaging during cold storage

Table 2 The effects of active packaging on microbial counts in beef during cold storage

	Total bacterial counts		
Storage (days)	C	T1	T2
1	$3.56^{d2)}$ ± 0.52	3.42^{c} ± 0.26	3.55^{c} ± 0.19
7	4.35^{Ac} ± 0.41	3.97^{Ac} ± 0.24	3.14^{Bc} ± 0.57
14	5.90^{Ab} ± 0.43	5.12^{Bb} ± 0.36	5.08^{Bb} ± 0.10
21	9.89^{Aa} ± 0.50	8.82^{Ba} ± 0.36	8.02^{Ca} ± 0.42
	Lactic acid bacteria		
Storage (days)	C	T1	T2
1	1.59^{c} ± 0.23	1.40^{c} ± 0.38	1.45^{c} ± 0.43
7	1.78^{Ac} ± 0.18	1.30^{Bc} ± 0.22	1.32^{Bc} ± 0.31
14	2.67^{Ab} ± 0.33	2.10^{Bb} ± 0.13	2.22^{Bb} ± 0.24
21	3.93^{Aa} ± 0.51	3.26^{Ba} ± 0.19	3.15^{Ba} ± 0.11
	E. coli		
Storage (days)	C	T1	T2
1	1.12^{d} ± 0.10	1.23^{c} ± 0.07	1.20^{c} ± 0.11
7	1.98^{Ac} ± 0.11	1.24^{Bc} ± 0.09	1.38^{Bb} ± 0.15
14	2.31^{Ab} ± 0.12	1.95^{Bb} ± 0.10	1.84^{Bab} ± 0.08
21	3.29^{Aa} ± 0.17	2.58^{Ba} ± 0.12	2.01^{Ca} ± 0.16

C: Ziplock bag packaging, T1: vacuum packaging, and T2: active packaging.
$^{A, B, C}$ Means ± SD with different superscripts in the same column differ significantly at $p<0.05$. $^{a, b, c, d}$ Means ± SD with different superscripts in the same row differ significantly at $p<0.05$.

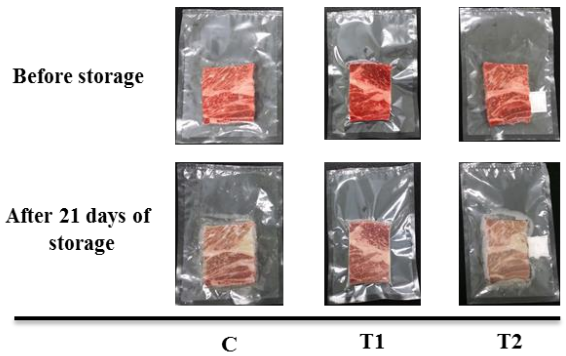

Figure 1 Representative image of packaged beef samples during cold storage.
C: Ziplock bag packaging, T1: vacuum packaging, and T2: active packaging.

without inducing any color deterioration. Another possible mechanism for the inhibitory effects of CO_2 could be the inhibition of substrate uptake by microorganisms [7] because the properties of

proteins are modified by CO_2 [8]. Thus, microbial growth can be decreased by the action of CO_2 in the environment of active packaging.

IV. CONCLUSION

In this study, for the first time, self-CO_2-generation materials have been reported for active packaging for the purpose of inhibiting the growth of microorganisms and for improving the shelf-life of beef. However, self-CO_2-generation materials (e.g., sodium bicarbonate and citric acid) are cheap and convenient to use. Moreover, sodium bicarbonate and citric acid are edible food additives. Therefore, the use of self-CO_2-generation materials for active packaging is a useful active packaging system. The CO_2 contents in active packaging were dramatically increased over the storage period by the self-CO_2-generation materials in this study (Fig. 1). At the end of the storage period, the CO_2 level was approximately 58%. Taken together, our data indicate that active packaging by using self-CO_2-generation material can extend the shelf-life similar to that observed with vacuum packaging, and that the active-packaging method can improve the quality characteristics of beef during cold storage.

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