EFFECT OF GAS COMPOSITION IN MODIFIED ATMOSPHERE PACKAGING ON THE STORAGE QUALITY OF SLICED BACON

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***Abstract*—Color, chemical quality, and sensory evaluation of sliced bacon was determined during storage. Sliced bacon were packed under four different modified atmosphere packaging (MAP), 80% O_2 + 20% CO_2 (80%O_2-MAP), 50% CO_2 + 50% N_2 (50%CO_2-MAP), 100% N_2 and air packaging (Air-P), and were stored at 5°C for 14 days. pH value of bacon under 80%O_2-MAP decreased and under Air-P increased during the storage. VBN value was higher in 80% O_2-MAP compared to other packaging methods. In instrumental color, L* value was higher in 80% O_2-MAP and Air-P, while a* value was higher in 50% CO_2-MAP and 100% N_2. In sensory evaluation, 50% CO_2-MAP and 100% N_2-MAP maintained the highest flavor point, while 50% CO_2-MAP alone maintained the highest visual color during the storage. Overall, sliced bacon packaged with 50% CO_2-MAP and 100% N_2-MAP showed better results in physical and chemical properties compared to other MAP methods.**

***Index Terms*—bacon, MAP, storage quality.**

I. INTRODUCTION

Bacon is made from skinned bellies, which have been cured and smoked until partially cooked. Smoking has been known as meat preservation method. The main purposes of smoking are to develop flavor, aroma, and color as well as to preserve meat and meat products (Pearson & Gillett, 1996). Because of the smoke components are absorbed by meat surface and penetrate only few milimeter, the preservative action of bacon is depends on the presence of the surface. The meat surface disruption, as in slicing, make the preservation effects essentially lost (Judge, Aberle, Forrest, Hedrick & Merkel, 1989). It is important to apply a correct packaging methods in order to preserve the sliced meat and meat products.

Modified atmosphere packaging is one of most developed packaging method. MAP is the removal or replacement of the gas sorounding the product (McMillin, 2008). MAP gasses include oxygen, carbon dioxide and nitrogen in different composition. High O_2 MAP preserved bright-red color and increase shelf life of fresh meat (Okayama, Muguruma, Murakami & Yamada, 1995), but resulted negative effects such as lipid oxidation (Jakobsen & Bertelsen, 2000) and off-flavor (Kim, Huff-Lonergan, Sebranek & Lonergan, 2010). Carbon dioxide is well known as antibacterial gas composition in MAP. Smith, Ramaswamy and Simpson (1990) described that 20-60% CO_2 in MAP are required to against aerobic spoilage effectively. In color, CO_2 MAP resulted color stability in pork (Jeremiah & Gibson, 1997), but has no effect upon meat color (Sorheim, Tore & Truls, 1997). The N_2 is an inert gas which can maintain the integrity of packaged since it is not reactive with meat pigment and nor absorbed by meat (McMillin, 2008), has minimal effect on metabolic reaction and lowly soluble in water and lipid (Church, 1994).

Because of the reducing preservatives action, as the effect of surface disruption (slicing) in meat, it is necessary to evaluate the suitable packaging methods of sliced bacon. This research was conducted to evaluate the effect gas composition in modified atmosphere packaging to the storage quality of sliced bacon.

II. MATERIALS AND METHODS

A. Sample preparation and experimental design

Fresh belly was smoked on chamber with temperature 60°C for 30 min. Bacon then was sliced about 4 mm-thickness. Three slices of bacon were placed on the tray (Max. O_2 transmission rate=0.1 cc/cm^2 at 23°C, 0% RH; Max. moisture vapor transmission rate= 2.0 g/24 hr-254 cm^2 at 38°C, 100% RH, Cryovac Sealed Air Corp., USA) for the following packaging methods. Tray was sealed with O_2 barrier film (Max. O_2 transmission rate=0.10 g/24 hr-254 m^2 at 4,4°C, 100% RH; Lid 1050, Cryovac Sealed Air Corp., USA), and filled with different gas composition (80% O_2+20% CO_2/80%O_2-MAP), 50%CO_2+50%N_2/50%CO_2-MAP), 100% N_2 and air packaging (Air-P) using modified atmosphere packaging machine (Hypervac, Korea) equipped with gas mixture (MAP Mix 9001 ME, PBI Dansensor, Denmark). Bacon was stored on refrigerator with temperature 5°C for 14 days.

B. pH determination

Ten gram of bacon was added with 100 ml distilled and then homogenized by 10,000 rpm for 1 min using homogenizer (PH91 SMT Co., Ltd., Japan). The pH value of sample solution was measured by using a pH meter (SevenEasy pH, Mettler-Toledo GmbH, Switzerland).

C. TBARS value

The TBARS (2-thiobarbituric acid reactive substance) value was measured according to Sinhuber and Yu (1977). Briefly, 0.5 g sample was mix with 3 drops of antioxidants solution, 3 ml of TBA solution, and 17 ml of 25% TCA. The mixture was heated at 98^{o} C for 30 min, and sentrifuged at 3,500 rpm for 30 min. An absorbance of supernatant was measured at 532 nm using a spectrophotometer (UV-mini-1240, Shimadzu, Japan). The results was calculated as milligram malonaldehid (MA) per kilogram sample.

D. VBN value

The VBN (volatile basic nitrogen) value was measured according to Kohsaka (1975). Briefly, 5 g sample was homogenized with 30 ml 5% TCA using a homogenizer (Ultra Turrax T25 basic, Ika Werke Gmbh & Co., Germany) at 13,500 rpm for 2 min. The homogenate was made up to 50 ml of final volume with 5% TCA and filtered using Whatman filter paper No. 1. One millimeter of filterate and 1 ml of borate buffer were placed in outer and inner of Conway dish, respectively, and incubated at 37^{o}C for 100 min. The inner solution were titrated with 0.01N HCl.

E. Instrumental color

The surface color were monitored by measuring the CIE L* (lightness), a* (redness), and b* (yellowness) using a chroma meter (CR-400, Konica Minolta Sensing Inc., Japan).

F. Sensory evaluation

A panel concisted of 6 panelists, evaluated the score of visual color and flavor. Evaluation scores for visual color and flavor were 9=very good, 7=good, 5=normal, 3=bad and 1=very bad.

G. Statistical analysis

All data were analyzed by SPSS 14.0 (2005). The data were analyzed by one way analysis of variance. Mean of data were compared using Duncan's multiple range tests with examination for significant differences (p<0.05).

III. RESULTS AND DISCUSSION

A. pH value

The pH value of sliced bacon packaged under all MAP methods was fluctuated during storage (Table 1). The pH value of bacon under 80% O_2-MAP was the highest by 1 day, and decreased during the storage. 50% CO_2-MAP resulted a stable pH value, around 6.31-6.48 during the storage. Generally increased pH value was found in air packaging from 3 d until 14 d of storage, in which increased from 6.11 to 6.39. Viana, Gomide and Vanetti (2005) showed that MAP did not show strong variation in pH of fresh pork loin. Difference results was reported by Sorheim, Kropf, Hunt, Karwoski and Warren (1996), in which the increasing percentage of carbon dioxide in MAP has been found to decrease pH value of pork.

B. TBARS value

Lipid oxidation of bacon packaged with modified atmosphere packaging is presented in table 1. A fluctuating TBARS value was found in all the MAP treatments. Bacon packaged with 80% O_2-MAP was the highest in TBARS value by 1 and 10 day, compared to other MAP methods. High concentration oxygen MAP may increase lipid oxidation and cause rancidity in pork loin (Cayuela, Gil, Banon & Garrido, 2004). In addition Lund, Hviid and Skibsted (2007) reported that the higher concentration of oxygen the higher lipid oxidation of chicken meat. Air packaging resulted lowest lipid oxidation among the treatments on 1, 3 and 10 day, while in other day was same. No difference in TBARS was found on 7 and 14 day of storage among MAP methods.

C. VBN value

VBN value of bacon in all packaging methods was increased as the increased of storage time (Fig. 1). This result is in agreement with Arashihar, Hisar, Kaya and Yanik (2004) who reported that VBN value increased as the increased of storage time in Air-P, vacuum and MAP. There was no difference in VBN value until 3 day of storage. VBN value of bacon under 80% CO_2-MAP was the highest in 7 to14 day of storage compared to other treatments. In opposite, 50% CO_2-MAP resulted the lowest VBN value from 7 to 14 day of storage. Lund, Hviid and Skibsted (2007) reported that high concentration of oxygen in MAP increased protein deteroriation of beef patties. No different was found in VBN value on 50% CO_2-MAP and 100% N_2 during the storage.

Table 1. Effect gas composition in modified atmosphere packaging to the pH value and TBARS value of sliced bacon during storage at 5°C

Storage time (day)	pH				TBARS(mg MA/kg sample)			
	80%O_2:20%CO_2	50%CO_2:50%N_2	100%N_2	Air-P	80%O_2:20%CO_2	50%CO_2:50%N_2	100%N_2	Air-P
1	6.45±0.03^{a}	6.39±0.04^{b}	6.28±0.20^{c}	6.19±0.05^{d}	0.32±0.10^{a}	0.26±0.04^{b}	0.25±0.05^{b}	0.23±0.04^{b}
3	6.35±0.06^{ab}	6.45±0.15^{a}	6.48±0.10^{a}	6.11±0.18^{b}	0.18±0.03^{b}	0.22±0.03^{b}	0.27±0.12^{a}	0.21±0.03^{b}
7	6.27±0.05^{b}	6.43±0.03^{a}	6.17±0.05^{c}	6.19±0.06^{bc}	0.22±0.04	0.21±0.04	0.23±0.07	0.22±0.04
10	6.05±0.04^{c}	6.31±0.01^{b}	6.41±0.01^{a}	6.38±0.06^{a}	0.31±0.05^{a}	0.31±0.04^{ab}	0.28±0.06^{ab}	0.26±0.04^{b}
14	5.87±0.11^{d}	6.48±0.08^{a}	6.03±0.17^{c}	6.38±0.15^{b}	0.22±0.05	0.23±0.03	0.20±0.07	0.22±0.03

$^{a-d}$ Values within each row with different superscripts are significantly different (p<0.05)

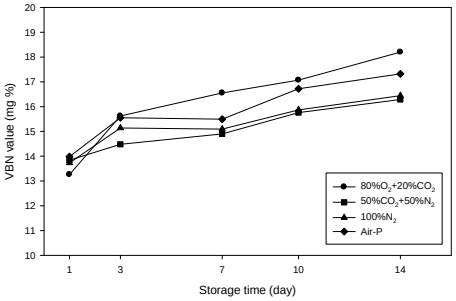

Fig. 1. Effect gas composition in modified atmosphere packaging to the VBN value of sliced bacon during storage at 5°C

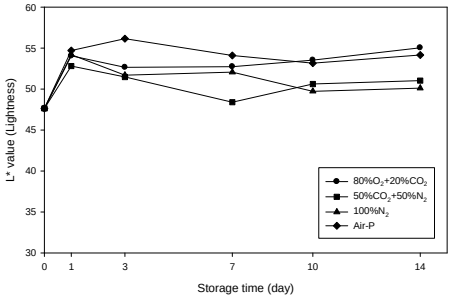

Fig. 2. Effect gas composition in modified atmosphere packaging to the L* value of sliced bacon during storage at 5°C

D. Instrumental color

Table 2. showed the instrumental color value of sliced bacon during the storage, including L* value (lightness), a* value (redness) and b* value (yellowness). The L* value of all treatments was fluctuated during the storage. The highest L* value was found in bacon under Air-P during the storage. No difference was found in L* value of bacon under 50% CO_2-MAP and 100% N_2-MAP. Same results was reported by Garcia-esteban, Ansorena and Astiasaran (2004) in which L* value of dry-cured ham under CO_2- and N_2-MAP was same. The redness in bacon under MAP was in contrast with L* value. Higher redness was found in bacon under 50% CO_2-MAP from 1 to 7 day, and in 100%N_2-MAP from 10 to 14 day. Different results were reported by Martinez, Djenane, Cilla, Beltran and Roncales (2006) who reported an intense red color in pork sausages packaged in high oxygen MAP, but this lasted only few days. No different was found in yellowness of bacon packaged with MAP on 1 day. Yellowness of bacon in all MAP treatments increased after 1 d until 7 d, then decreased until the end of storage 14 d. No significant different also was found by Garcia-esteban, Ansorena and Astiasaran (2004) in yellowness of dry cured ham under vacuum and MAP.

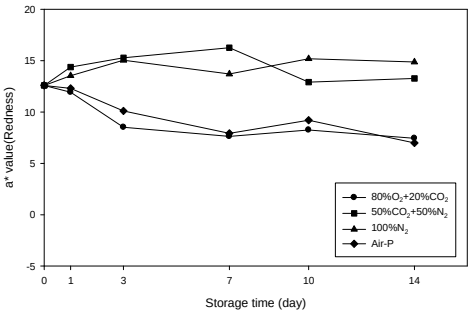

Fig. 3. Effect gas composition in modified atmosphere packaging to the a* value of sliced bacon during storage at 5°C

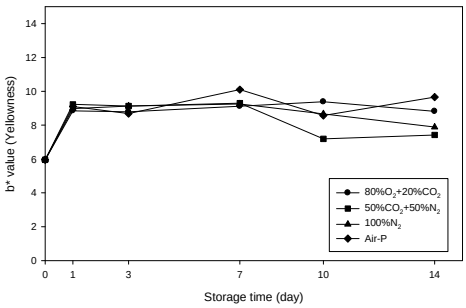

Fig. 4. Effect gas composition in modified atmosphere packaging to the b* value of sliced bacon during storage at 5°C

Table 2. Effect gas composition in modified atmosphere packaging to the visual color and flavor value of sliced bacon during storage at 5°C

Storage time (day)	Visual color				Flavor			
	80%O_2:20%CO_2	50%CO_2:50%N_2	100%N_2	Air-P	80%O_2:20%CO_2	50%CO_2:50%N_2	100%N_2	Air-P
0	8.7±0.7	8.7±0.7	8.7±0.7	8.7±0.7	9.0±0.0	9.0±0.0	9.0±0.0	9.0±0.0
1	8.0±0.7^{b}	9.00±0.0^{a}	9.0±0.0^{a}	8.0±0.5^{b}	9.0±0.0	9.0±0.0	9.0±0.0	9.0±0.0
3	5.7±0.7^{c}	9.0±0.0^{a}	7.5±0.5^{b}	5.8±0.8^{c}	8.4±0.5^{b}	9.0±0.0^{a}	9.0±0.0^{a}	8.4±0.5^{b}
7	1.0±0.0^{d}	8.0±0.0^{a}	6.3±0.5^{b}	3.2±0.4^{c}	6.1±0.8^{b}	8.6±1.0^{a}	8.8±0.4^{a}	6.6±0.6^{b}
10	1.0±0.0^{d}	7.8±0.0^{a}	6.2±0.4^{b}	2.0±0.1^{c}	5.6±0.6^{b}	8.0±0.6^{a}	8.0±0.3^{a}	6.0±0.3^{b}
14	1.0±0.0^{c}	7.0±0.0^{a}	6.2±0.2^{b}	1.0±0.0^{c}	5.0±0.1^{b}	7.8±0.3^{a}	7.6±0.6^{a}	5.1±0.2^{b}

$^{a-d}$ Values within each row with different superscripts are significantly different (p<0.05)

E. Sensory evaluation

Table 2. showed visual color and flavor sensory evaluation of bacon packaged with MAP. Panelists scored 50% CO_2-MAP as the highest in visual color, followed by 100% N_2-MAP, Air-P and 80% CO_2-MAP respectively. This results is in agreement with the instrumental color results, especially redness. Meat color, especially redness is one of the most important quality parameter that determines the consumer acceptance of meat (Ahn and Nam, 2004; Mancini *et al.*, 2006). Both bacon under 80% O_2-MAP and Air-P were in critical point (5 point) on 3 d of storage. Critical point represented the unacceptable color for panelists. At the end of storage, bacon packaged with 50% CO_2 and 100% N_2 still showed acceptable scores by panelists (7 and 6.2, respectively). Flavor sensory evaluation also showed the same

results with visual color sensory evaluation. Panelists scored the bacon under 50%CO_2-MAP and 100% N_2-MAP as the highest scores in flavor sensory evaluation. Bacon under 80% O_2-MAP were in critical point on 10 day, while bacon under Air-P on 14 day. Bacon under both 50% CO_2-MAP and 100% N_2-MAP were acceptable until the end of storage time. The flavor sensory evaluation is related with lipid oxidation (TBARS) and protein deteroriation (VBN). The same correlation also was reported by Kim, Huff-Lonergan, Sebranek and Lonergan (2010), in which High-Ox MAP increased lipid oxidation and higher off-flavor in beef steak.

IV. CONCLUSION

This study concluded that 50% CO_2-MAP and 100% N_2-MAP showed better storage quality of sliced bacon including lipid oxidation, protein deteroriation, instrumental color, and sensory evaluation compared with 80% O_2-MAP and air packaging. This storage quality results is just basic study in sliced bacon packaging. Extended research related with shelf life and other chemical changes in sliced bacon under those two gas compositions is needed in future.

ACKNOWLEDGEMENT

This study was supported by Technology Development Program for Agriculture and Forestry (108061-03-2-HD120), Ministry for Agriculture, Forestry and Fisheries, Republic of Korea.

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