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Lipolytic and proteolytic properties of dry-cured boneless hams ripened in modified atmospheres

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Abstract

We studied proteolytic and lipolytic properties of dry-cured boneless ham (porcine *quadriceps femoris*) made with chilled (10°C, 48 h) or frozen/thawed meat (frozen at −20°C frozen for 90 days and followed by thawing at 10°C for 48 h) were determined. Dry-cured meats were stored in modified atmosphere packages (100% N_2 and a mixture of 75% N_2 + 25% CO_2) at 15°C with the intention of reducing ripening space. Results showed that dry-cured hams made with frozen/thawed raw meat had more salt, volatile fatty acids and free fatty acid content after salting and smoking. Whereas, samples prepared with chilled meats contained more nitrogenous compounds (water-soluble nitrogen, non-protein nitrogen, and free amino acids). Volatile and free fatty acid contents in all samples significantly increased with storage. Acetic acid was the predominant volatile fatty acid. To confirm lipolytic activity in dry-cured ham stored in modified atmospheres, we calculated the lipolytic coefficient. The lipolytic coefficients of all samples were positive values and significantly ($P < 0.05$) increased with storage indicating lipolysis in samples were still active. Furthermore, nitrogenous compounds in dry-cured ham significantly ($P < 0.05$) increased with storage indicating proteolysis in samples were not affected by modified atmosphere storage. Aerobic, anaerobic and lactic acid bacteria counts in dry-cured meats were stable to modified atmospheres storage for 20 weeks at 15°C. Flavor, texture and color score in sensory evaluation for dry-cured ham made with chilled meat were significantly higher than that made with frozen/thawed meat. All samples had high overall acceptance scores in sensory evaluation. Results in this study suggested that dry-cured boneless ham stored in modified atmospheres for 20 weeks at 15°C was another feasibility to ripen the meat without affecting lipolysis, proteolysis, microbiology and sensory quality.

Keywords: Dry-cured boneless ham; Ripening; Modified atmospheres

1. Introduction

Increasing consumption of dry-cured ham products has raised the interest in standardization of procedures and acceleration of curing (Lin et al., 1990; Marriott, Graham, & Claus, 1992; Warren & Kastner, 1992). Generally, European and American type dry-cured hams were ripened in a temperature and relative humidity controlled room for a long time. Insufficient space and equipment requirements for a long-term repining have limited the mass production and raised costs of this product for majority of dry-cured ham products firms in Taiwan. Nevertheless, production was limited to traditional preparation within winter (climate temperature 15–20°C) to avoid quality defect and wholesomeness failure in the salting process. Therefore, developing an alternative way to reduce the requirement of ripening space as well as standardization of this process has been strongly encouraged.

Unique aroma and flavor characteristics that were attributable to enzymatic activities and chemical reactions in dry-cured hams develop during ripening (Arobles & Julia, 1992; Careri, Mangia, Barbieri, Bolzoni, Virgili, & Paralari, 1993; Toldra, 1992; Ventanas, Cordoba, Antequera, Garcia, lopez-Bote, & Asensio, 1992). It has been implicated that ripening condition could affect biochemical activities on meat proteins and lipids in dry-cured hams (Cordoba, Antequerra, Ventanas, Lopez-Bote, Garcia, & Asensio, 1994). Modified atmosphere packaging has been used to stabilize the physicochemical characteristics and prolong the shelf stability of foods (Brody, 1989). Much attention was concentrated on the microbiological and color stability of fresh meats and sensory properties of cooked meats

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products packed in a modified atmosphere (Gill & Jones, 1994; Jeremiah, Penny, & Gill, 1992; Robson, Collison, & Macfie, 1989; Zhao, Wells, & Marshall, 1994). The feasibility of modified atmosphere for ripening dry-cured meats has not been well studied.

The objective of this study was to evaluate microbiology quality, sensory quality, lipolytic and proteolytic properties in dry-cured boneless ham ripened in modified atmospheres.

2. Materials and methods

2.1. Preparation of dry-cured boneless ham

All meats (1–1.2 kg per *quadriceps femoris*) used in this study were excised from 24-h postmortem porcine carcasses (95–110 kg live wt.) regardless of crossbreed or sex. Sixty chilled meats (10°C, 48 h) and sixty frozen/thawed meats (frozen at −20°C for 90 days and followed by thawing at 10°C for 48 h) were used to prepare dry-cured hams. Meat surfaces were dry rubbed with mixture of adjunct and cure (35 g salt, 8 g sucrose, 0.015 g nitrite, 1 g nitrate, and 3 g of potassium sorbate/kg of raw meat) and held at 5°C for 10 days. Each cured sample was stuffed in a water permeable cellulose casing (150 mm in diameter) and the meat was pressed by a 250 kg flat stainless steel plate at 5°C for 5 days. Samples were dried in a 20°C, RH 80–85% smokehouse for 2 days and then smoked at 25°C, RH 80% for 24 h by igniting dried sugar cane dregs dust.

2.2. Packaging of dry-cured boneless ham

Dry-cured boneless hams were packed in PVC/CPP rigid containers (140×110×60 mm). Packages were evacuated, flushed modified atmospheres (100% nitrogen, 75% nitrogen +25% carbon dioxide) and automatically thermal sealed by a Multivac R7000 packaging unit using PET/aluminum foil/CPP film. All packages were stored at 15°C for 20 weeks.

2.3. Experimental design and sampling

Experiment was designed as a factorial (meat×atmosphere×storage time) spilt plot with three replications. Four packages of each treatment were taken removed from 2, 4, 8, 12, 16 and 20 weeks. Samples were finely ground for physicochemical and biochemical analyses.

2.4. Microbiology determination

The 25 g of finely ground sample was homogenized with 225 ml of sterile peptone water. One milliliter of 10-fold serial dilutions was poured on a petri dish for determinations. Aerobic plate count was enumerated on a plate count agar at 30°C for 48 h. Anaerobic plate count and lactic acid bacteria were incubated anaerobically on thioglycollate agar and MRS agar at 30°C for 72 h, respectively. Bacteria counts were expressed as colony forming unit per gram of sample (CFU/g).

2.5. Composition, water activity and pH determination

Protein, fat and moisture contents in samples were determined according to the methods of AOAC (1984). The pH values was determined by homogenizing of 10 g ground sample with 90 ml distilled water and then measured with a pH meter equipped with a glass electrode. The salt content was measured by the method of Koniecko (1985). Water activity of ground samples were measured by a Novasina Humidat-IC II unit (Novasina AG, Zurich, Switzerland).

2.6. Lipolytic activity measurement

2.6.1. Lipid extraction

Total lipid was extracted from the ground sample with chloroform/methanol (2:1, v/v) according to the procedure of Folch, Lees, and Stanely (1957).

2.6.2. Volatile fatty acid (VFA) determination

VFA in dry-cured meat was determined according to the steam distillation method of Halvarson (1972) with a Buchi distillation unit. The VFA distillate was titrated with 0.05 N NaOH and expressed as mg acetic acid/100 g fat.

Ethylene esterification of VFA was prepared according to the methods of Halvarson (1972). The VFA composition was determined with a Hewlett-Packard 6894 gas chromatography equipped with a flame ionization detector. GC conditions were: a fused silica capillary column RTX-1 (30 m×0.25 mm i.d. 0.25 μm film thickness, Resteck Co., Bellefonte, PA, USA); temperature programming from 40°C for 4 min to 140°C for 4 min at 20°C/min rise; injector 220°C; detector at 250°C; carrier gas, nitrogen at 40 ml/min. The chromatogram peak was integrated with a Hewlett-Packard 3396 integrator. Six standards of fatty acid methyl esters purchased from Sigma Co. were monitored; acetic acid, butyric acid, isobutyric acid, valeric acid, isovaleric acid and hexanoic acid.

2.6.3. Free fatty acid (FFA) determination

Ten grams of ground sample mixed with 20 ml of chloroform and 0.5 g of sodium sulfate for 5 min, and then filtered through Whatman No. 4 filter paper. The free fatty acid in the 25 ml of filtrate was titrated with 0.01 N potassium hydroxide-ethanol. Free fatty acid content was expressed as g oleic acid/100 g fat. Extraction and methyl esterification of free fatty acid in 0.2 g of meat lipid was prepared according to the method of Christie (1982).

2.6.4. Non-free fatty acid (NFFA) determination

The water washing collected from the preparation of free fatty acid fraction was acidified with 1 ml of 6 N hydrochloric acid, extracted twice with 10 ml n-hexane and then removed the organic solvent was removed with a flow of nitrogen. Methyl esterification of the non-free fatty acid fraction was prepared according the method of Christie (1982).

2.6.5. Measurement of fatty acid composition in FFA and NFFA

Fatty acid compositions of free fatty acid and non-free fatty acid were measured with the same GC equipped with a flame ionization detector. GC conditions were according to previous description (Wang, Jiang, & Lin, 1995).

2.6.6. Lipolytic coefficient calculation

Lipolytic coefficient was calculated according to the method of Samelis, Aggelis & Metaxopoulos (1993) with minor modification and followed by equation:

$$k = \text{FA in FFA}t - \text{FA in TFFA0}/\text{FA in NFFA0}$$

where

FA in TFFAt: unsaturated fatty acid content in free fatty acid stored at t week;

FA in TFFA0: unsaturated fatty acid content in free fatty acid before storage;

FA in NFFA0: unsaturated fatty acid content in non-free fatty acid before storage.

2.7. Proteolytic activity determination

2.7.1. Water soluble nitrogen (WSN) content

Ten gram of meat was homogenized twice with 50 ml deionised water and centrifuged at $5000\times\boldsymbol{g}$, 4°C for 10 min. The pellet was re-homogenized and centrifuged as mentioned. Combination of supernatant was filtered through Whatman No. 1 filter paper. The WSN in 25 ml of filtrate was determined the nitrogen content with the Kjeldahled method (AOAC, 1984).

2.7.2. Non-protein nitrogen (NPN) content

The 25 ml of above-mentioned filtrate mixed with 25 ml of 20% trichloroacetic acid, settled at room temperature for 30 min, centrifuged at $5000\times\boldsymbol{g}$, 4°C, 10 min and filtered through Whatman No. 4 filter paper. The nitrogen content in 25 ml of filtrate was determined according to Kjeldaheld method.

2.7.3. Free amino acid (FAA) content

Free amino acids were determined according to the method of Church, Swaisgood, Porter, and Catignani (1983) with minor modification. Aliquot of the TCA-precipitated filtrate was added with 3ml of *o*-phthaldehyde reagent. The reagent was prepared volumetrically (50 ml) with 40 mg of *o*-phthaldehyde dissolving in 5 ml ethanol, 25ml, 0.1 M sodium tertborate, 0.1 ml of β-mercaptoethanol and deionized water. The absorbance of sample mixture was read at 340 nm against the *o*-phthaldehyde reagent. The FAA content was calculated tyrosine as standard and expressed as mg tyrosine/100 g dry matter.

2.8. Sensory evaluation

Thirty untrained consumer panels evaluated flavor, texture, color, odor and overall acceptance of dry-cured boneless ham. Samples were evaluated on seven-point scale (0 = poor, 6 = excellent). Samples were cut into 2 cm^2, cooked in a 150°C conventional oven to 72°C core temperature and then served for sensory evaluation.

2.9. Statistical analysis

Data were analyzed with General Linear Model Procedure of SAS/package (SAS Institute Inc, 1988). Comparison of treatment was based on Duncan's multiple range test (Montgomery, 1991).

3. Results and discussion

3.1. Attributes of dry-cured boneless hams

To reduce the space for long-term ripening dry-cured ham, we sought to store dry-cured ham in the modified atmospheres and elucidate whether lipolytic and proteolytic activities in meat were affected by this process. We first compared the composition in dry-cured hams prepared with chilled and frozen/thawed meats after salting and smoking. Results showed that protein and fat contents in dry-cured ham significantly increased, whereas moisture decreased after salting and smoking processes (Table 1).

3.1.1. Salt content

It was found that salt content in dry-cured ham made with frozen/thawed meat was significantly higher ($p < 0.05$) than that made with chilled meat (Table 1) after salting and smoking. It is well believed that frozen storage produce profound effects on the structural changes via damage effect of ice crystal growth on muscle fiber morphology association with increase in drip loss during thawing (Miller, Ackerman, & Palumbo, 1980). Long-term frozen storage caused denaturation of

Table 1
Attributes of raw meat and dry-cured boneless ham

	Raw meat		Dry-cured boneless ham[a]	
	Chilled	Frozen/thawed	Chilled	Frozen/thawed
Moisture (%)	73.1±1.5a[b]	70.2±0.7a	61.4±1.1b	59.1±0.9b
Protein (%)	20.7±0.4a	21.8±0.3b	23.2±0.5c	24.6±0.7d
Fat (%)	6.0±0.3a	7.2±0.5b	8.1±0.3c	9.2±0.5d
pH	5.9±0.1a	5.7±0.1a	5.5±0.1a	5.6±0.1a
Salt (%)	Not detected	Not detected	5.2±0.2a	5.8±0.1b
Water activity(%)	99.2±0.3a	98.6±0.4a	94.2±0.3b	93.6±0.4c

[a] Dry-cured boneless hams were sampled after smoking.
[b] Mean±standard error, $n=12$; data shown in the column with the same letter is not significant difference.

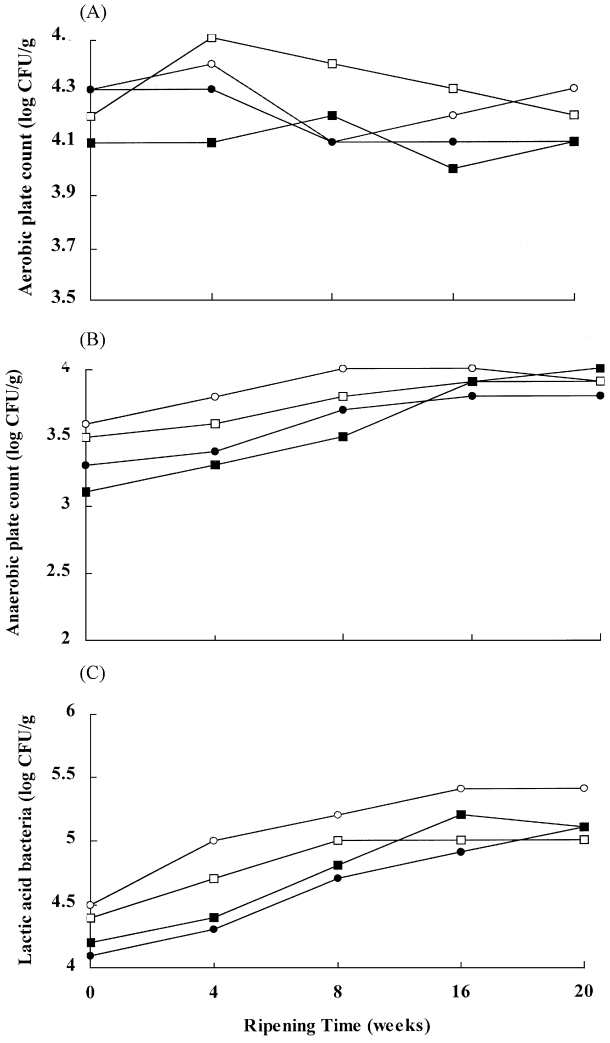

Fig. 1. Effect of various modified atmosphere packaging on microbiology quality of dry-cured boneless hams. (A) aerobic plate count; (B) anaerobic plate count; (C) Lactic acid bacteria count; ●, Chilled, 100% N_2; ■: Chilled, 75% N_2 + 25% CO_2; ○, Frozen/thawed, 100% N_2; □, Frozen/thawed, 75% N_2 + 25% CO_2.

meat protein and affected the penetration of curing agents (Kang, Ito, & Fukazawa, 1983; Wagnor & Anon, 1986). Therefore, higher salt content in dry-cured ham made with frozen/thawed meat might be due to more salt penetration into meat structure. Higher salt content in dry-cured ham made with frozen/thawed meat in this study was similar to Arnau, Guo, and Guerrero (1994) and Banon, Cayuela, Granados, and Garrido (1999) conducted on Spanish dry-cured hams prepared with pre-freezing raw meats.

3.1.2. Water activity

To store dry-cured ham for 20 weeks at 15°C, we should develop a sufficient bacteriostatic effect to hurdle microbiology growth in meat. It was believed that water activity played an important role in stabilization of microbiology quality in shelf stable dry-cured meat products. Results showed that water activity in dry-cured ham was at a range of 0.936–0.942 (Table 1) after salting and smoking. Water activity in this study was similar to certain German and Italian shelf stable meat products (Leistner, 1992).

3.2. Microbiology quality

We further investigated whether dry-cured ham packed in modified atmospheres for long-term storage at 15°C affected the microbiology quality. Results showed that aerobic and anaerobic counts for all treatments were stable to storage (Fig. 1) and met the local official general hygienic requirement (aerobic plate count < 6.5 $\log_{10}$ CFU/g). Lactic acid bacteria count slightly increased; however, no sensible sour odor in samples was evaluated at the end of the storage. Results suggested that stability of microbiology quality was attributed to lower water activity in dry-cured ham and bacteriostatic effect of modified atmospheres.

3.3. Lipolytic properties of dry-cured boneless hams

3.3.1. VFA content

The VFA content in dry-cured ham made with frozen/thawed meat was 22.1–28.1% higher than that that made with chilled meat after salting and smoking process. The VFA content in dry-cured ham significantly increased ($P < 0.05$) after 4 weeks' storage. Furthermore, the VFA content in dry-cured ham stored in 100% N_2 was significantly higher than that stored in the mixture of 75% N_2 + 25% CO_2 (Fig. 2). Dry-cured ham made with chilled meat and stored in 100% N_2 had the maximum VFA content.

3.3.2. VFA composition

We further explored the fatty acid composition in VFA. It was found that acetic acid was the predominant volatile fatty acid among six volatile fatty acid compositions measured, and contained 36.5–42.4% VFA content in all treatments (Fig. 3). Acetic acid content in dry-cured ham made with frozen/thawed meat was significantly higher ($P < 0.05$) than that made with chilled meat. Furthermore, acetic acid content in dry-cured ham stored in 100% N_2 was significantly higher ($P < 0.05$) than that stored in 75% N_2 + 25% CO_2. Acetic acid content in all treatments significantly increased after 4 weeks storage. We found that dry-cured ham prepared with frozen/thawed meat and stored in 100% N_2 for 12 weeks contained the maximum acetic acid content in VFA. The concentrations of the other five volatile fatty acids varied with treatment, but no significant differences were detected (data are not shown).

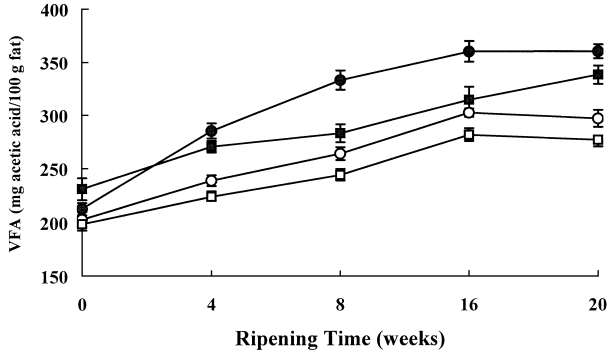

Fig. 2. Effect of various modified atmosphere packaging on the volatile fatty acid content of dry-cured boneless hams. ●, Chilled, 100% N_2; ■: Chilled, 75% N_2 + 25% CO_2; ○, Frozen/thawed, 100% N_2; □, Frozen/thawed, 75% N_2 + 25% CO_2.

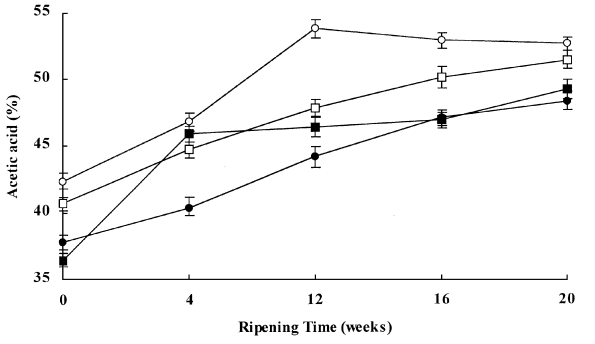

Fig. 3. Effect of various modified atmosphere packaging on the acetic acid content of dry-cured boneless hams. ●, Chilled, 100% N_2; ■: Chilled, 75% N_2 + 25% CO_2; ○, Frozen/thawed, 100% N_2; □, Frozen/thawed, 75% N_2 + 25% CO_2.

3.3.3. FFA content

There is no significant difference in FFA content in dry-cured ham made with frozen/thawed meat or chilled meat after salting and smoking (Fig. 4). We found that FFA content in dry-cured ham stored in 100% N_2 was significantly ($P < 0.05$) higher than that stored in 75% N_2 + 25% CO_2 after 8 weeks' storage. The FFA content in all treatments significantly increased after 20 weeks' storage ($P < 0.05$), however no rancid odor was detected. The composition in five fatty acid ester measured in dry-cured ham were various with raw meats used and modified atmospheres packaging (data were not shown). Higher VFA and FFA contents in dry-cured ham prepared with frozen/thawed meat may be attributable to lipid oxidation enhanced by freezing as reported by Motilva, Toldra, Nadal, and Flores (1994) and followed by a series of chemical reactions. In this study, the VFA and FFA in dry-cured ham stored in modified atmospheres increased with storage suggesting that lipid degradation and lipid oxidation in samples remained active.

3.3.4. Lipolytic activity

To confirm the lipolytic activity in dry-cure ham stored in modified atmosphere, we calculated the lipolytic coefficients from unsaturated fatty acids content in FFA and NFFA (Fig. 5). Results showed that all treatments had positive lipolytic coefficient of unsaturated fatty acid. The coefficient values significantly increased with storage. The samples made with made with frozen/thawed raw meats and stored in 100% N_2 had the

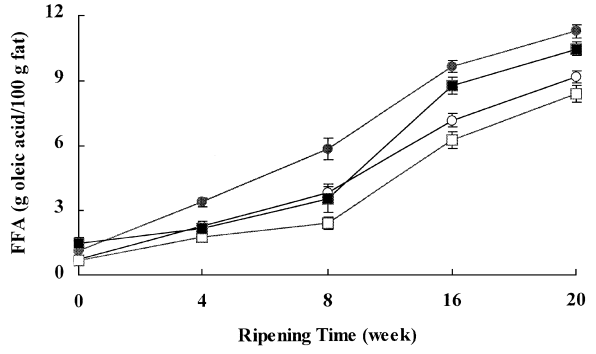

Fig. 4. Effect of various modified atmosphere packaging on the free fatty acid content of dry-cured boneless hams. ●, Chilled, 100% N_2; ■: Chilled, 75% N_2 + 25% CO_2; ○, Frozen/thawed, 100% N_2; □, Frozen/thawed, 75% N_2 + 25% CO_2.

maximum lipolytic activity. On the base of lipolytic coefficient, lipid in dry-cured ham stored in modified atmospheres at 15°C was subject to continuous degradation. These phenomena were similar to conventional-made Spanish dry-cured ham (Motilva, Toldra, Nieto, & Flores, 1993) and French dry-cured ham (Busccailhon, Monin, Cornet, & Bousset, 1994).

3.4. Proteolytic activities of dry-cured boneless hams

3.4.1. WSN content

We further studied whether proteolyic compound formation in dry-cured ham was affected by raw meat or modified atmosphere storage. Results showed that WSN content in samples made with chilled meat was significantly higher than that made with frozen/thawed treatment meat after salting and smoking (Fig. 6). The WSN content in the sample stored in 100% N_2 was significantly higher ($P<0.05$) than that stored in 75% $N_2+25\%$ CO_2. The WSN content in all treatments significantly increased after 20 weeks storage.

3.4.2. NPN and FAA content

Not only the NPN content but also the FAA content in dry-cured ham prepared with chilled meat was higher ($P<0.05$) than that made with frozen/thawed meat (Figs. 7 and 8). There were no significant difference in NPN or FAA content in samples stored in 100% N_2 and the mixture of 75% $N_2+25\%$ CO_2. The NPN and FAA contents in all treatments significantly ($P<0.05$) increased with storage.

Contribution of the proteolysis and lipolysis to the physicochemical and sensory quality of dry-cured ham products has been reported (Antequera et al., 1992; Berdague, Denoyer, Le Quere, & Semon, 1991). It has been implicated that frozen/thawing induced the nitrogenous compounds loss accompany with drip loss (Lawrie, 1985). In this study, the WSN content in dry-cured ham made with frozen/thawed meat was less than that made with chilled meat might be attributable to the drip loss in the process of thawing. Reports suggested that the degradation effect of protease on meat protein caused the increase of NPN content in dry-cured meat

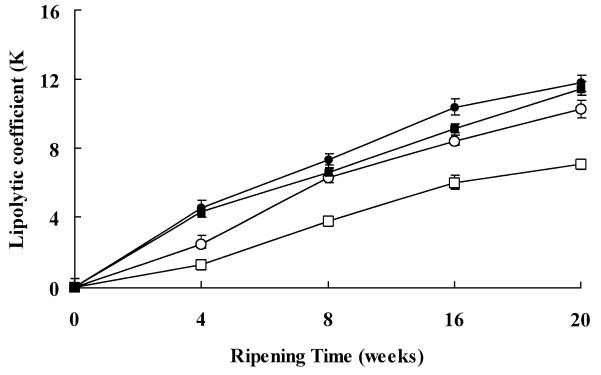

Fig. 5. Effect of various modified atmosphere packaging on the lipolytic coefficient of dry-cured boneless hams. ●, Chilled, 100% N_2; ■: Chilled, 75% $N_2+25\%$ CO_2; ○, Frozen/thawed, 100% N_2; □, Frozen/thawed, 75% $N_2+25\%$ CO_2.

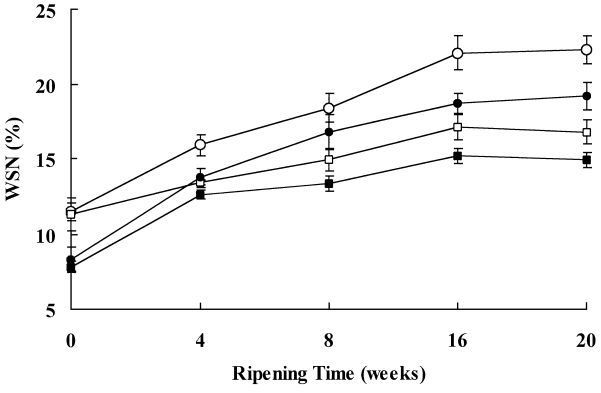

Fig. 6. Effect of various modified atmosphere packaging on the water soluble nitrogen content of dry-cured boneless hams. ●, Chilled, 100% N_2; ■: Chilled, 75% $N_2+25\%$ CO_2; ○, Frozen/thawed, 100% N_2; □, Frozen/thawed, 75% $N_2+25\%$ CO_2.

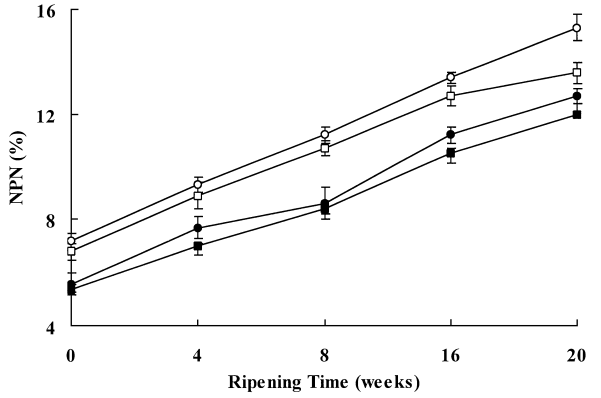

Fig. 7. Effect of various modified atmosphere packaging on the non-protein nitrogen content of dry-cured boneless hams. ●, Chilled, 100% N_2; ■: Chilled, 75% $N_2+25\%$ CO_2; ○, Frozen/thawed, 100% N_2; □, Frozen/thawed, 75% $N_2+25\%$ CO_2.

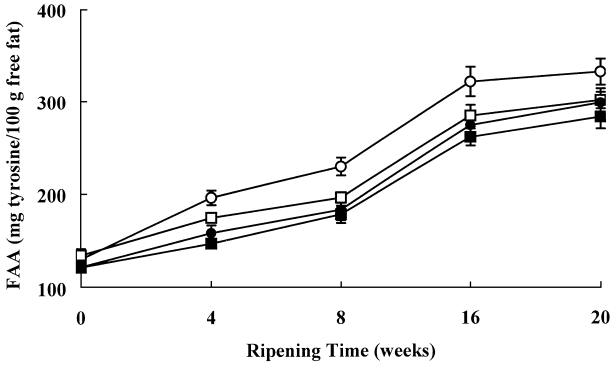

Fig. 8. Effect of various modified atmosphere packaging on the free amino acid content of dry-cured boneless hams. ●, Chilled, 100% N_2; ■: Chilled, 75% $N_2+25\%$ CO_2; ○, Frozen/thawed, 100% N_2; □, Frozen/thawed, 75% $N_2+25\%$ CO_2.

Table 2
Sensory evaluation of dry-cured boneless ham ripened in modified atmosphere[a]

	Chilled		Frozen/thawed	
	100% N_2	75% N_2 + 25% CO_2	100% N_2	75% N_2 + 25% CO_2
Flavor	4.8±0.3a[b]	5.5±0.2b	4.3±0.4a	5.0±0.2a
Texture	4.3±0.6a	4.5±0.5a	3.7±0.4b	3.9±0.3b
Color	5.2±0.6a	5.6±0.2a	3.4±0.4b	3.8±0.3b
Odor	2.7±0.6a	2.2±0.8a	3.1±0.6a	2.8±0.7a
Acceptance	4.6±0.2a	5.1±0.3a	4.3±0.5a	4.8±0.7a

[a] Samples were evaluated on seven-point scale (0 = poor, 6 = excellent).
[b] Mean±standard error, $n = 12$; data shown in the column with the same letter significant difference.

product (Buscailhon, Gandemer, & Monin, 1994). The proteolysis and lipolysis in dry-cured ham were mainly attributed to the microflora (Bermell, Molina, Miralles, & Flores, 1993; Molina, Nieto, Flores, Silla, & Bermell 1991) and endogenous enzymatic activities during ripening. The endogenous enzyme such as cathepsin B, L, and H in Spanish dry-cured ham were still active during ripening (Parreno, Cusso, Gill, & Sarraga, 1994). We suggested that meat protein and lipid degradation by endogenous enzyme or natural microflora resulting in an increase of proteolytic and lipolytic compounds in dry-cured ham stored in modified atmospheres for 20 weeks at 15°C.

3.5. Sensory evaluation

Study was finally to elucidate the sensory quality of dry-cured ham. Results of sensory evaluation were shown in Table 2. Sample made with chilled meat and stored in 75% N_2 + 25% CO_2 had the best flavor score. Texture and color scores for samples prepared with chilled meat were significantly higher than that made with frozen/thawed meat. There was no significant difference in odor score or odor defect comment for all samples. All treatments had higher sensory acceptability.

4. Conclusion

In this study, we found that dry-cured ham stored in modified atmospheres for 20 weeks at 15°C caused an increase of lipolytic and proteolytic compound without affecting microbiology quality. With the intention of reducing the requirement of ripening space, storing dry-cured boneless ham in a modified atmosphere package was subject to an alternative way to ripening of dry-cured ham. However, several complicated biochemical interactions with meat, microflora and cure agents might be involved in proteolysis and lipolysis activities in dry-cured meat products. Further study will be needed to elucidate the contribution of endogenous enzymes and natural microflora in meat to the flavor compound formation in dry-cured ham stored in modified atmospheres. On the other hand, taking advantage of modified atmospheres ripening and development, a more time-effective for dry-cured ham ripening, such as the addition of exogenous lipase or protease to accerelate flavor formation in dry-cured ham is to be studied.

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