

## Quality Evaluation of Pork with Various Freezing and Thawing Methods

Su Kyung Ku, Ji Yun Jeong, Jong Dae Park, Ki Hong Jeon, Eun Mi Kim, and Young Boong Kim\*

*Division of Convergence Technology, Processing Technology Research Group,  
Korea Food Research Institute, Sungnam 463-746, Korea*

### Abstract

In this study, the physicochemical and sensory quality characteristics due to the influence of various thawing methods on electro-magnetic and air blast frozen pork were examined. The packaged pork samples, which were frozen by air blast freezing at  $-45^{\circ}\text{C}$  or electro-magnetic freezing at  $-55^{\circ}\text{C}$ , were thawed using 4 different methods: refrigeration ( $4\pm 1^{\circ}\text{C}$ ), room temperature (RT,  $25^{\circ}\text{C}$ ), cold water ( $15^{\circ}\text{C}$ ), and microwave (2450 MHz). Analyses were carried out to determine the drip and cooking loss, water holding capacity (WHC), moisture content and sensory evaluation. Frozen pork thawed in a microwave indicated relatively less thawing loss (0.63-1.24%) than the other thawing methods (0.68-1.38%). The cooking loss after electro-magnetic freezing indicated 37.4% by microwave thawing, compared with 32.9% by refrigeration, 36.5% by RT, and 37.2% by cold water in ham. The thawing of samples frozen by electro-magnetic freezing showed no significant differences between the methods used, while the moisture content was higher in belly thawed by microwave (62.0%) after electro-magnetic freezing than refrigeration (54.8%), RT (61.3%), and cold water (61.1%). The highest overall acceptability was shown for microwave thawing after electro-magnetic freezing but there were no significant differences compared to that of the other samples.

**Keywords:** electro-magnetic frozen, thawing, frozen meat, thawing loss, water holding capacity, pork quality

### Introduction

Frozen storage is an important way to preserve meat that is frequently used as raw material for many meat products, or directly used for the preparation of different dishes (Carballo *et al.*, 2000). Freezing and thawing mainly influence the water fraction of meat. Since water is contained within and between the muscle fibers of meat, compartments are created in the tissue, which complicates the process. As the water freezes, the concentration of the remaining solutes (proteins, carbohydrates, lipids, vitamins and minerals) increases, thereby disrupting the homeostasis of the complex meat system (Lawrie, 1998). The increase in crystal sizes during storage can be explained by the recrystallization process. During storage, preferential growth in the solid state of large crystals occurs at the expense of smaller ones (Meryman, 1956). Freezing delays food decay and the growth of microorganisms (Jeong *et al.*, 2006; Nam *et al.*, 2000; Ngapo *et*

*al.*, 1999; Yoon, 2002). However, the extent of quality loss in frozen meat is dependent upon many factors, including the rate of freezing and thawing, the thawing method, the specific storage temperature, and temperature fluctuation (Gomez-Guillen *et al.*, 2003). Frozen foods need to be thawed before any subsequent food processing or cooking can be done. The purpose of thawing is to restore the original food quality as much as possible (Kondratowicz *et al.*, 2006). There are many frozen food thawing methods available, including cold water thawing (Bailey and James, 1974; Vanichseni *et al.*, 1972), microwave thawing (Basak and Ayappa, 2002; Zeng and Faghri, 1994), refrigerator thawing (Anderson and Singh, 2006), and high-pressure thawing (Denys *et al.*, 2000). Deterioration by freezing is caused by the formation of large extracellular ice crystals (Reid, 1997; Sebranek, 1982), lipid oxidation (Keller and Kinsella, 1973; Morrissey *et al.*, 1998), protein oxidation, protein denaturation (Levine *et al.*, 1990; Xiong, 2000), and microbiological growth (Pham, 1994) during the thawing process. In many experiments concerning the quality of frozen foods, thawing has gained relatively little attention (Jul, 1984). However, the quality of frozen food deteriorates more by the thawing process than by the freezing process, as the tha-

\*Corresponding author: Young Boong Kim, Division of Convergence Technology, Korea Food Research Institute, Sungnam 463-746, Korea. Tel: +82-31-780-9180, Fax: +82-31-780-9076, E-mail: kybaaa@kfri.re.kr

wing process requires more time (Hong *et al.*, 2007; Zhu *et al.*, 2004). For this reason, a number of studies have examined and developed different thawing methods, such as high-pressure thawing (Makita, 1992; Zhao *et al.*, 1998; Zhu *et al.*, 2004), ohmic thawing (Bozkurt and IÇier, 2012; Hong *et al.*, 2007; Icier *et al.*, 2010; Yun *et al.*, 1998), microwave thawing (Bengtsson and Ohlsson, 1974; Kang *et al.*, 2008; Lee and Park, 1999) and hot-air thawing (Kim *et al.*, 1990). Thus, the objective of this study is to compare the physicochemical and sensory evaluation of pork following various thawing methods and, moreover, to increase industrial applications of the appropriate thawing method for pork frozen by electric magnetic (EM) freezing and air blast (AB) freezing.

## Materials and Methods

### Samples

Samples of this study were purchase from local distributor at 24 h after slaughter. The pork was used belly and ham (*M. Biceps femoris*, *M. Semitendinosus*, *M. Semimembranosus*) were sampled. This study selects belly and ham which have different lipid contents, and compared two parts. The samples were cut to 5-7 cm thickness and were packed with aerobic packaging (23×32 cm, polyethylene) by the 500 g.

### Freezing and thawing

Samples were subjected to freezing in electro-magnetic (EM) freezer (AVI Co., Japan) of Dine jeju Co. and in air blast (AB) freezer (Ratem ENG, Korea) until -55°C and -45°C were reached in the meat, which were measured by using data logger (Testo 176T4, Germany) and thermocouple (NiCr-Ni thermocouple, SEF GmbH, Germany). For thawing pork, thawing by refrigeration at 4±1°C (LG MicomCA-A11AC, Korea), thawing by room temperature (RT), and thawing by cold water were carried out at 25°C and 15°C, respectively, and thawing by microwave was carried out using a microwave (Samsung Co. RE-551B, 2450 MHz, 700 W, Korea) until the temperature of the meat reached 0°C. Microwave thawing produced fast thawing, it might cause pronounced protein denaturation and destabilization (Srinivasan *et al.*, 1997). Microwave thawing requires shorter thawing time and smaller space for processing, and reduces drip loss, microbial problems and chemical deterioration (Meisel, 1973). Therefore, samples were evaluated until their core temperature reached at 0°C and repeated 20 times for each sample as a preparatory experiment about overheating of surface. Tha-

wing time using refrigeration, RT, cold water and microwave was 164.9 h, 5.0 h, 1.5 h and 0.4 h, respectively.

### Analysis items and methods

Thawing time was used in sampling as a result of preparatory experiment and temperature of sample for analysis was measured after thawing. After thawing of frozen pork physicochemical and sensory evaluation was carried out in order to compare the quality of each result and repeated three times for each sample. Sensory evaluation was carried out after heating the thawed samples and the results were applied to statistical analysis.

### Thawing loss

Thawing loss (%) is measured for frozen pork until the temperature in center of meat reaches at 0°C.

$$\text{Thawing loss (\%)} = \{(\text{weight before thaw} - \text{weight after thaw}) / \text{weight before thaw}\} \times 100$$

### Cooking loss

According to specific methods of thawing, the sample weight is measured before/after cooking of the sample by heating at 75°C in a water bath, and is taken out when the temperature in center of the test material reaches at 65°C, and then cooled, after which cooking loss is calculated by following formula.

$$\text{Cooking loss (\%)} = \{(\text{weight before cook} - \text{weight after cook}) / \text{weight before cook}\} \times 100$$

### Water holding capacity (WHC)

WHC of meat depending on each thawing method, using the modified Kristensen and Purslow (2001) method, is calculated by heating 5 g of minced meat at 70°C in a water bath for 30 min and then cooling it, and then centrifuging at 1,000 rpm for 10 min and measuring total moisture, after which is calculated by the following formula.

$$\text{WHC (\%)} = (\text{total water content} - \text{separated water content}) \times 0.951^* / \text{total water contents} \times 100$$

\*0.951: pure water amount for meat moisture which is separated under 70°C

### Moisture contents

Moisture content is analyzed at 105°C by an ambient drying method according to AOAC (1990).

### Sensory evaluation

A sensory evaluation of samples was carried out based on appearance, flavor, texture, taste and overall acceptability with a scale of 9 points, and by 15 inspectors who are chosen among personnel with more than 1 year of experience in meat-related and sensory testing. Its score is indicated by 1 point (very poor) to 9 point (very good). For this sensory test, the samples are cut to 1 cm of thickness and heated using an electrical grill (Phillips HD-4417, Netherlands) until the core temperature of meat reaches 75°C, after which was provided to the inspectors for sensory evaluation on a white dish.

### Statistical analysis

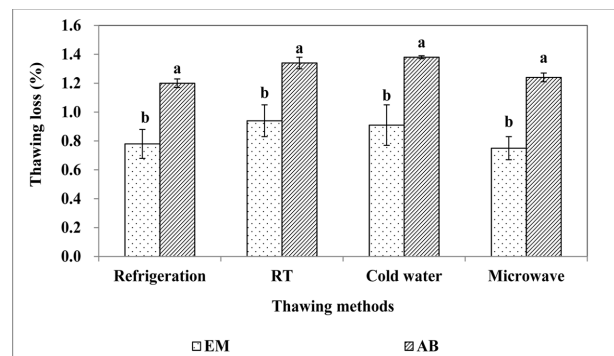
The results from this test were applied to analysis of variance using SAS program (2002) and its significance was verified at the level of 5% using Duncan's multiple range test.

## Results and Discussion

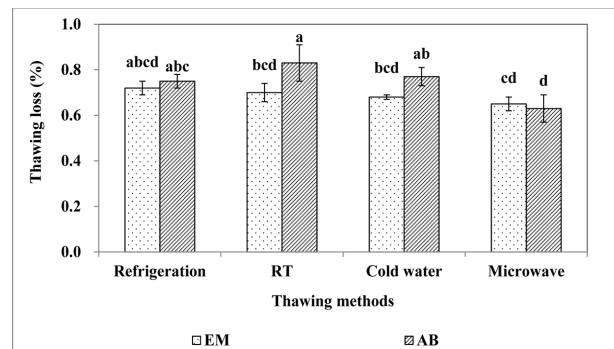
### Thawing loss

The change in the thawing loss of pork after thawing according to the different thawing methods is shown in Figs. 1 and 2. Fig. 1 indicates the thawing loss in belly as a result of the various freezing and thawing methods. In general, the thawing loss resulting from any thawing method following AB freezing was higher than that following EM freezing. The thawing loss due to AB freezing with microwave thawing was lower (0.65%) than the other freezing and thawing methods. However, there was no significant difference in the thawing loss after EM freezing, regardless of the thawing method. There was also no significant difference in the thawing loss of samples frozen by EM freezing. This showed that there was a total of 4.4-9.7% and 5.0-10.1% reduction in the thawing loss effect compared to thawing by refrigeration, RT and cold water.

Fig. 2 shows the thawing loss in ham resulting from each of the thawing methods. There was no significant difference in the thawing loss after EM freezing by thawing method. After EM freezing, the thawing loss in ham thawed by refrigeration, RT, cold water and microwave showed values of 0.78%, 0.94%, 0.91% and 0.75%, respectively. The thawing loss after AB freezing showed a similar pattern to EM freezing. Refrigeration resulted in 1.20%, RT 1.34%, cold water 1.38%, and microwave 1.24% thawing loss. This demonstrated that ham thawed by refrigeration and microwave resulted in less thawing



**Fig. 1. Thawing loss of pork in belly with various freezing and thawing methods.** <sup>1</sup>)Refrigeration: 4±1°C; <sup>2</sup>) RT (Room temperature): 25°C; <sup>3</sup>) Cold water: 15°C tap water; <sup>4</sup>) Microwave: Thawing method using microwave oven; <sup>5</sup>) EM: Electro-magnetic freezing (-55°C); <sup>6</sup>) AB: Air blast freezing (-45°C); <sup>a,b</sup>Different letters indicate significant differences within the freezing and thawing methods ( $p < 0.05$ ).



**Fig. 2. Thawing loss of pork in ham with various freezing and thawing methods.** <sup>1</sup>)Refrigeration: 4±1°C; <sup>2</sup>)RT (Room temperature): 25°C; <sup>3</sup>)Cold water: 15°C tap water; <sup>4</sup>)Microwave: Thawing method using microwave oven; <sup>5</sup>)EM: Electro-magnetic freezing (-55°C); <sup>6</sup>) AB: Air blast freezing (-45°C); <sup>a-d</sup>Different letters indicate significant differences within the freezing and thawing methods ( $p < 0.05$ ).

loss than RT and cold water thawing. The total thawing loss effect after EM freezing and AB freezing, compared with the four thawing methods, was 3.8-20.2% and 4.0-21.0% (Fig 1). A high thawing loss means a loss of soluble water from muscle fiber, indicating a loss of nutrition. This is similar to the results of Lee and Park (1999), indicating that thawing by microwave is faster than thawing by common methods, and that the amount of thawing loss is reduced compared with thawing at temperatures higher than 4°C. This is not desirable from an economical aspect, and indicates a similar pattern with the result from Konratowicz *et al.* (2008) report that microwave thawing results in less thawing loss for pork than thawing by RT, reported by. Therefore, the results of this study showed

that meats thawed using microwave thawing after EM freezing could reduce the thawing loss resulting from freezing and thawing, which is believed to contribute to the maintenance of quality.

### Cooking loss, WHC and moisture contents

Cooking loss, WHC and moisture contents in belly which was thawed by each thawing method after EM freezing and AB freezing are shown in Table 1. Cooking loss was 28.2-32.6% for belly, depending on the freezing and thawing methods. Cooking loss in belly was 28.2% after EM freezing with refrigeration thawing which was lower than those of the other freezing and thawing methods. But cooking loss in belly for each freezing and thawing method showed no significant difference. Although WHC in belly for each freezing method showed no significant difference, the 60.7% by refrigeration and 59.5% by microwave showed higher WHC than the other thawing methods (57.7-59.2%). Moisture contents from ham with refrigeration thawing indicated the highest rate, at 62.1% after EM freezing and 61.5% after AB freezing, respectively ( $p < 0.05$ ).

Table 2 showed the results of cooking loss, WHC and moisture contents for thawed ham depending on the thawing methods after being frozen by EM or AB freezing. Cooking loss was 32.9-37.4% after EM freezing, depending on the thawing methods, and 23.1-35.9% after AB freezing. Refrigeration thawing had the lowest values, 32.9% and 23.1%, respectively, regardless of the freezing method ( $p < 0.05$ ). Although WHC after EM freezing showed no significant difference, WHC thawing by refrigeration (59.9%) showed a slightly higher WHC than thawing by RT (59.3%), cold water (59.3%) and microwave (59.8%). In contrast, WHC after AB freezing in ham thawed with refrigeration was lower (57.3%) than RT (58.8%), cold water (58.3%) and microwave (59.4%) ( $p < 0.05$ ). Moisture contents of belly thawed by microwave was 62.0% after EM freezing and 63.1% after AB freezing, respectively ( $p < 0.05$ ).

Cooking loss for frozen ham thawed by refrigeration after AB freezing was lower than the other freezing and thawing methods ( $p < 0.05$ ) in contrast with the thawing loss. WHC and moisture contents of the samples after thawing were comparatively higher, regardless of the cut

**Table 1. Cooking loss, water holding capacity and moisture contents of pork in belly with various freezing and thawing methods** (Unit: %)

Treatments	Refrigeration <sup>1)</sup>		RT <sup>2)</sup>		Cold water <sup>3)</sup>		Microwave <sup>4)</sup>	
	EM <sup>5)</sup>	AB <sup>6)</sup>	EM	AB	EM	AB	EM	AB
Cooking loss	28.2±3.4	30.4±1.9	31.3±0.5	29.4±0.1	32.5±1.0	29.6±0.3	32.6±0.6	30.8±2.8
WHC <sup>7)</sup>	60.7±3.6	59.2±0.8	58.5±0.4	57.7±1.0	58.6±0.7	57.8±1.0	58.6±0.3	59.5±0.6
Moisture contents	62.1±0.5 <sup>a</sup>	61.5±0.5 <sup>a</sup>	55.9±1.0 <sup>bcd</sup>	55.1±0.8 <sup>cd</sup>	56.1±0.8 <sup>bcd</sup>	54.6±1.2 <sup>d</sup>	56.9±1.0 <sup>bc</sup>	57.9±1.2 <sup>b</sup>

<sup>1)</sup>Refrigeration: 4±1°C

<sup>2)</sup>RT (Room temperature): 25°C

<sup>3)</sup>Cold water: 15°C tap water

<sup>4)</sup>Microwave: Thawing method using microwave oven

<sup>5)</sup>EM: Electro-magnetic freezing (-55°C)

<sup>6)</sup>AB: Air blast freezing (-45°C)

<sup>7)</sup>Appearance, flavor, texture, taste and overall acceptability (1=very poor, 9=very good)

<sup>a-d</sup>Means within row different superscripts are significantly differences by freezing and thawing methods ( $p < 0.05$ ).

**Table 2. Cooking loss, water holding capacity and moisture contents of pork in ham with various freezing and thawing methods** (Unit: %)

Treatments	Refrigeration <sup>1)</sup>		RT <sup>2)</sup>		Cold water <sup>3)</sup>		Microwave <sup>4)</sup>	
	EM <sup>5)</sup>	AB <sup>6)</sup>	EM	AB	EM	AB	EM	AB
Cooking loss	32.9±1.3 <sup>c</sup>	23.1±1.0 <sup>d</sup>	36.5±0.7 <sup>ab</sup>	35.9±1.3 <sup>ab</sup>	37.2±0.7 <sup>a</sup>	33.7±0.6 <sup>bc</sup>	37.4±0.1 <sup>a</sup>	34.8±2.4 <sup>abc</sup>
WHC <sup>7)</sup>	59.9±1.9 <sup>a</sup>	57.3±0.8 <sup>b</sup>	59.3±0.8 <sup>ab</sup>	58.8±0.1 <sup>ab</sup>	59.3±0.8 <sup>ab</sup>	58.3±0.8 <sup>ab</sup>	59.8±0.3 <sup>a</sup>	59.4±0.5 <sup>ab</sup>
Moisture contents	54.8±3.2 <sup>b</sup>	54.6±1.4 <sup>b</sup>	61.3±0.8 <sup>a</sup>	60.4±0.8 <sup>a</sup>	61.1±1.0 <sup>a</sup>	59.9±1.0 <sup>a</sup>	62.0±0.8 <sup>a</sup>	63.1±1.0 <sup>a</sup>

<sup>1)</sup>Refrigeration: 4±1°C

<sup>2)</sup>RT (Room temperature): 25°C

<sup>3)</sup>Cold water: 15°C tap water

<sup>4)</sup>Microwave: Thawing method using microwave oven

<sup>5)</sup>EM: Electro-magnetic freezing (-55°C)

<sup>6)</sup>AB: Air blast freezing (-45°C)

<sup>7)</sup>Appearance, flavor, texture, taste and overall acceptability (1=very poor, 9=very good)

<sup>a-d</sup>Means within row different superscripts are significantly differences by freezing and thawing methods ( $p < 0.05$ ).

of meat. Kim *et al.* (2006) reported that drip was reduced and WHC increased when frozen pork is thawed by ohmic thawing at 250W microwave power. In addition, Bailey and James (1974) reported that adjustment of the air flow rate is recommended.

### Sensory evaluation

A sensory evaluation was carried out for thawed pork depending on the thawing method (refrigeration, RT, cold water and microwave) after EM freezing and AB freezing. The results are shown in Table 3. The sensory evaluation for the belly showed no significant differences. The texture from the sensory evaluation of the belly, depending on each thawing method after EM freezing, indicated 7.4 points for refrigeration, 6.4 points for RT, 7.4 points for cold water and 7.2 points for thawing by microwave. The texture of samples frozen by AB indicated 7.1 points for refrigeration thawing, 6.4 points for RT thawing, 7.4 points for cold water and 6.9 points for microwave thawing. In addition, overall acceptability was the highest for thawing by microwave (7.1 points) and cold water (7.6

points), while the lowest values in the belly were obtained for thawing by RT and refrigeration, regardless of whether EM or AB freezing was used.

Results of the sensory evaluation of ham are shown for each thawing method in Table 4. Although there are no significant differences, ham frozen by EM showed a higher value (8.1 points) in texture for RT thawing than for thawing by cold water (8.0 points), microwave (7.9 points) and refrigeration (6.7 points). After AB freezing, the texture was given 7.3 points for microwave thawing, which was higher than the other thawing methods (6.6-7.0 point). In addition, the overall acceptability for ham was 7.9 points for EM freezing, obtained by microwave thawing, and 7.1 points for AB freezing, obtained by refrigeration thawing. Although the sensory evaluation showed no significant differences for the freezing and thawing methods used, overall acceptability was higher when microwave thawing was applied. Lee *et al.* (2007) reported that there is a difference in the texture and juiciness when frozen pork is thawed at varying temperatures. Similarly, the results from of this study showed differ-

**Table 3. Sensory evaluation of pork in belly with various freezing and thawing methods**

(Unit: point)

Treatments	Refrigeration <sup>1)</sup>		RT <sup>2)</sup>		Cold water <sup>3)</sup>		Microwave <sup>4)</sup>	
	EM <sup>5)</sup>	AB <sup>6)</sup>	EM	AB	EM	AB	EM	AB
Appearance <sup>7)</sup>	7.8±1.5	7.4±0.8	7.6±0.9	7.7±0.5	7.6±0.9	7.3±0.5	7.6±0.5	7.0±0.5
Flavor	7.7±1.2	7.6±0.5	7.2±0.8	7.4±0.9	7.4±1.0	7.3±0.7	8.0±0.5	7.4±0.5
Texture	7.4±1.6	7.1±0.8	6.4±1.3	6.4±0.5	7.4±1.1	7.4±0.9	7.2±1.3	6.9±1.2
Taste	7.2±1.5	7.1±1.0	6.9±0.9	6.6±0.7	7.4±1.0	7.3±0.9	7.9±0.8	7.4±0.7
Overall acceptability	7.1±1.6	7.0±0.8	7.0±0.9	6.6±0.7	7.6±0.9	7.1±0.8	7.6±0.7	7.1±0.8

<sup>1)</sup>Refrigeration: 4±1°C

<sup>2)</sup>RT (Room temperature): 25°C

<sup>3)</sup>Cold water: 15°C tap water

<sup>4)</sup>Microwave: Thawing method using microwave oven

<sup>5)</sup>EM: Electro-magnetic freezing (-55°C)

<sup>6)</sup>AB: Air blast freezing (-45°C)

<sup>7)</sup>Appearance, flavor, texture, taste and overall acceptability (1=very poor, 9=very good)

**Table 4. Sensory evaluation of pork in ham with various freezing and thawing methods**

(Unit: point)

Treatments	Refrigeration <sup>1)</sup>		RT <sup>2)</sup>		Cold water <sup>3)</sup>		Microwave <sup>4)</sup>	
	EM <sup>5)</sup>	AB <sup>6)</sup>	EM	AB	EM	AB	EM	AB
Appearance <sup>7)</sup>	7.6±1.2	7.9±0.8	7.6±0.9	7.4±0.5	7.6±0.9	7.4±0.5	7.6±0.5	7.4±0.5
Flavor	7.5±1.4	7.7±0.5	7.9±0.8	6.6±0.5	7.6±0.9	7.1±0.4	7.9±0.3	7.0±0.7
Texture	6.7±1.5	7.0±0.9	8.1±0.8	7.0±0.5	8.0±0.5	6.6±1.0	7.9±0.3	7.3±0.7
Taste	6.8±1.5	7.2±0.8	7.4±1.2	6.9±0.3	7.6±0.9	7.0±0.8	7.9±0.6	7.0±0.7
Overall acceptability	6.8±1.6	7.1±1.0	7.2±1.1	6.7±0.5	7.6±0.9	6.9±0.8	7.9±0.6	7.0±0.7

<sup>1)</sup>Refrigeration: 4±1°C

<sup>2)</sup>RT (Room temperature): 25°C

<sup>3)</sup>Cold water: 15°C tap water

<sup>4)</sup>Microwave: Thawing method using microwave oven

<sup>5)</sup>EM: Electro-magnetic freezing (-55°C)

<sup>6)</sup>AB: Air blast freezing (-45°C)

<sup>7)</sup>Appearance, flavor, texture, taste and overall acceptability (1=very poor, 9=very good)

ences for each thawing method.

## Conclusion

Freezing is one of the most important preservation methods for meat and meat products, since it leads to a minimal loss of quality during long-term storage compared with other methods. This study showed that meat thawed by microwave after EM freezing indicated low thawing loss. Cooking loss and WHC in belly for each freezing and thawing method showed no significant different while moisture contents refrigeration thawing method lower than the other thawing methods, regardless of freezing method ( $p < 0.05$ ). Cooking loss of ham was the lowest by thawed refrigeration after AB freezing ( $p < 0.05$ ). Sensory evaluation showed no significant differences regardless of freezing and thawing methods. Therefore, it was shown that EM freezing and microwave thawing is an appropriate way to reduce the deterioration of meat quality.

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