

## Changes in Nucleotide Compounds, and Chemical and Sensory Qualities of Duck Meat during Aging at 0°C

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### Abstract

The objective of this study was to identify appropriate aging conditions, changes in nucleotide-related compounds, chemical changes, and a sensory evaluation of duck meat during aging at 0°C for 7 d. Twenty one 45-day-old Pekin white ducks samples were separated into breast and leg meat. ATP was not detected for almost the entire aging period because ATP was depleted immediately after slaughter. Inosine monophosphate (IMP) was highest on day 1 (26.69 μmol/g), and then it rapidly decreased to 7.11 μmol/g on day 7. However, this level was not different between breast and leg meat. Hypoxanthine (Hx) content of breast meat was 14.88 μmol/g, whereas that of leg meat was 16.41 μmol/g. Inosine content of breast meat was double than that of leg meat. The pH values of breast and leg meat were 5.90-6.05 and 6.23-6.73, respectively, during the aging period. Volatile basic nitrogen content of breast and leg meat increased during aging. Breast meat had good sensory evaluation scores for flavor (7.4), juiciness (6.8), tenderness (7.2), and overall acceptance (7.4) on day 3. Similar to breast meat, leg meat also had good sensory evaluation scores. Therefore, it is concluded that the appropriate aging period is 3 d for duck breast meat and 1 day for leg meat at 0°C.

**Key words:** aging, duck, 0°C, nucleotide, VBN

### Introduction

Taste and nutritional value is important for consumers of meat; therefore, consumption of high-protein, low-calorie poultry meat is increasing due to increased income (Kim *et al.*, 2005). Among the poultry meats, duck meat is a healthy food as reported in references such as Donguibogam and Bonchogangmok (Chae *et al.*, 2006). Different from chicken, the color of duck breast meat is red, so it has similar sensory characteristics to beef (Kang *et al.*, 2006a). Brooke and Kaiser (1970) reported that duck fat is high in unsaturated fatty acids and essential fatty acids such as linolic acid (C18:2) and linolenic acid (C18:3).

After slaughter, muscle goes through a post-mortem process and then begins to relax during aging. Generally, aging of meat changes its characteristics significantly depending on the aging conditions. Dransfield (1992) reported that the degree of meat aging is related to aging tempera-

ture; the higher the temperature, the shorter the aging process. Aging of meat affects its taste, flavor, and acceptability; therefore, appropriate aging is very important (Liu *et al.*, 2007). Mateo *et al.*(1996) reported that besides the four basic tastes (sweet, salty, sour, and bitter), there is another taste called umami. According to Marcus (2009), umami is important for balancing the four basic tastes, flavor, and texture. Moreover, free amino acid and nucleotide-related compounds are taste compounds involved in the taste of meat (Kawamura and Halpem, 1987).

Nucleotide-related compounds result from the decomposition of adenosine triphosphate (ATP), which is quite variable in content depending on aging conditions (Flores *et al.*, 1999). Before slaughter, ATP is the major compound in muscle, whereas only small amounts of adenosine diphosphate (ADP) and adenosine monophosphate (AMP) are found. However, muscle contains large amounts of inosine monophosphate (IMP) and small amounts of ATP, AMP, and ADP after slaughter (Choi *et al.*, 1995; Lee and Lee, 2001). ATP becomes AMP by dephosphorylation and is then converted to IMP, which provides good taste to meat (Tikk *et al.*, 2006). Aging is the most important factor related to the amount of IMP (Meinert *et al.*, 2009). For example, over-aged meat does not always

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taste good, although tenderness improves, because IMP changes to inosine, and then to hypoxanthine (Hx), which has a bitter taste. Therefore, excessive aging can make meat more tender but result in poor taste (Cho *et al.* 2008). Many studies have been carried out on taste compounds in various meats, including those on pork (Choi *et al.*, 1995; Flores *et al.*, 1999; Meinert *et al.*, 2009; Tikik *et al.*, 2006), chicken (Ahn *et al.*, 2002), and fish (Cho *et al.*, 2003; Lee and Lee, 2001; Ozogul *et al.*, 2000; Sung and Shim, 1981; Valle and Malle, 1998; Valls *et al.*, 2001). However, research on changes in nucleotide-related compounds in duck meat during the aging process has not been reported yet.

This study was carried out to observe quantity changes in nucleotide-related compounds as well as chemical and sensory quality changes in duck meat during aging at 0°C.

## Materials and Methods

### Sample preparation

Forty five day-old Pekin white ducks were used as the duck meat samples. After slaughter, 21 carcass samples were refrigerated at 0±1°C for 7 d after vacuum-packing. Three carcasses were used daily. Each of the carcasses was deboned and separated into breast and leg lean meat for analyses.

### Nucleotide-related compound analysis

Nucleotide-related compounds were extracted accord-

ing to the method of Valle and Malle (1998). Briefly, 10 g of duck meat was homogenized with 20 mL of 0.6 M perchloric acid, and the homogenate was centrifuged at 15,000×g for 15 min at 2°C. The pH of the supernatant was adjusted to 6.5-6.8 with 5 M KOH, and the samples were allowed to sit at 4°C for 10 min before injecting a 20 µL aliquot into a high performance liquid chromatography (HPLC, Jasco PU-2089, Japan). The HPLC conditions are shown in Table 1. The identity and quantity of the nucleotide-related compounds were assessed by comparison to standards with known retention times and peak areas (Sigma, USA).

### pH

The pH values of 5 g sample homogenates were measured using a pH meter (Accumet model 13-620-530A, Fischer, USA) in samples prepared with distilled 45 mL distilled water. Every determination was performed in triplicate.

### Volatile basic nitrogen (VBN)

The VBN (mg%) test was performed to determine the extent of protein deterioration during refrigerated aging. VBN was measured by modified micro-diffusion assay according to the Standards for Processing & Ingredient Specifications of Livestock Product method (SPISLP, 2011).

$$\text{VBN (mg\%)} = [(a - b) \times (0.14 \times f \times 100 \times d) / S]$$

where a is the sample titer, b is the blank titer, f is a

**Table 1. Changes in sensory characteristics of uncooked and cooked duck meat during aging at 0°C**

Treatments		Aging period (d)								
		0	1	2	3	4	5	6	7	
Fresh duck meat	Appearance	Breast	7.5±1.0	8.2±0.8	7.4±0.5	7.8±0.4	7.8±0.4	6.2±0.8	6.2±0.8	7.2±0.8
		Leg	6.3±1.2	8.6±0.5	7.2±1.4	7.4±0.5	6.6±0.9	6.0±1.0	5.0±1.0	7.2±0.4
	Color	Breast	7.7±0.8	7.6±0.9	5.2±1.6	6.4±1.5	6.2±1.1	5.6±1.1	5.8±1.3	7.6±0.5
		Leg	4.7±1.8	6.6±2.1	6.2±1.1	6.2±1.1	6.6±0.5	4.0±1.0	6.0±1.0	7.0±1.7
	Off flavor	Breast	2.5±1.0	1.4±0.5	4.6±1.7	4.8±1.3	5.2±1.5	5.0±0.7	5.6±0.9	6.0±1.2
		Leg	2.3±1.2	1.2±0.4	4.4±1.3	4.2±1.1	4.2±1.5	5.6±0.5	6.0±1.0	5.8±1.3
	Overall acceptance	Breast	7.2±1.2	7.6±1.6	7.0±1.4	7.0±0.7	6.8±0.8	5.6±0.5	5.2±0.3	6.4±1.1
		Leg	6.0±1.4	7.6±1.1	6.5±1.6	6.6±1.7	6.6±0.5	5.4±0.5	5.6±0.9	5.4±0.9
Cooked duck meat	Flavor	Breast	7.2±1.0	7.2±1.0	7.4±0.9	7.2±0.8	6.4±0.9	6.2±0.8	5.8±0.8	5.0±0.7
		Leg	7.2±2.1	7.2±0.4	6.8±1.1	6.8±1.3	6.4±1.1	5.8±0.4	4.8±0.4	5.0±1.2
	Juiciness	Breast	5.7±1.2	5.8±1.3	6.8±0.8	6.8±1.6	5.4±0.5	5.4±0.5	4.8±0.8	6.6±1.1
		Leg	5.8±1.9	7.2±1.1	7.2±1.3	7.0±1.9	6.6±1.3	6.0±0.7	4.6±0.9	5.6±2.3
	Tenderness	Breast	5.3±1.6	4.6±0.5	5.0±0.7	7.2±1.5	5.4±1.8	5.4±0.5	5.0±1.2	6.8±0.8
		Leg	5.3±1.5	4.6±0.5	6.4±1.1	7.0±1.9	7.0±1.6	6.4±0.5	5.2±1.3	5.4±0.9
	Overall acceptance	Breast	6.7±1.5	6.8±1.2	7.0±0.7	7.4±0.9	6.2±0.8	5.4±0.5	4.8±0.8	6.0±0.7
		Leg	6.7±1.0	7.4±1.3	6.8±1.3	6.8±0.8	6.6±1.1	6.0±0.7	4.6±1.1	5.8±0.8

reagent factor,  $d$  is the sample dilution, and  $S$  is sample weight (g)

### Sensory evaluation

A sensory evaluation of the duck meat during aging was carried out by 30 trained panelists (15 males and 15 females) using uncooked and cooked meat samples. The uncooked meat was evaluated for appearance, color, off-flavor, and overall acceptance. The cooked meat was evaluated for flavor, juiciness, tenderness, and overall acceptance. Each sample was evaluated using a 9-point hedonic rating scale.

### Statistical analysis

Data were analyzed using SAS software (SAS Institute, USA), and Duncan's multiple range test was used to compare differences between means. Significance was defined at  $p < 0.05$ .

## Result and Discussion

### Nucleotide-related compounds

Meat taste is influenced by various factors such as fat, free amino acids, nucleotide-related compounds, minerals, and sugars (Kato *et al.*, 1989). However, Yamaguchi (1991) reported that IMP has a strong influence on taste. Nucleotide-related compounds change according to the following process: ATP → ADP → AMP → IMP, inosine, and Hx (Lee and Lee, 2001; Terasaki, 1965; Valle and Malle, 1998). In other words, AMP changes to IMP, which gives meat good flavor and taste (Tikk *et al.*, 2006).

Fig. 1 shows the peak areas and retention times for ATP, ADP, AMP, IMP, inosine, and Hx as standard materials. Figs. 2 and 3 show changes in the nucleotide-related compounds of duck breast and leg meat during aging at 0°C. The ATP value was 0.06-0.89 μmol/g in breast meat, and no differences were observed during the aging period, indicating that ATP was metabolized immediately after slaughter. Ahn and Park (2002) reported that ATP is not detectable in chicken 48 hours after slaughter. Depending on the aging period, the ADP value was 1.02-1.90 μmol/g, and the AMP value was 0.33-0.88 μmol/g in breast meat. The ADP value in leg meat was 1.02-1.90 μmol/g, and the AMP value was 0.33-0.88 μmol/g, which were

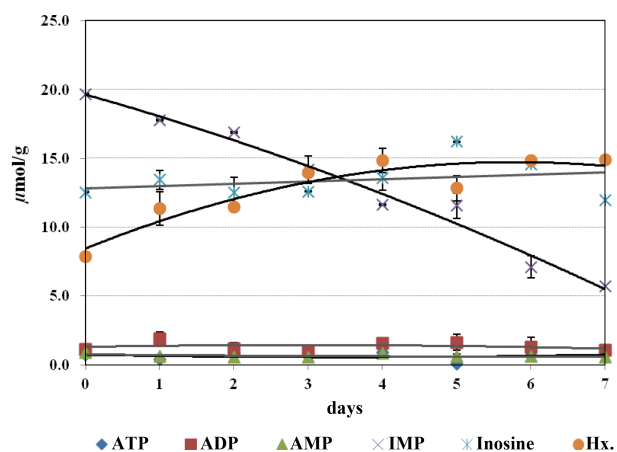


Fig. 2. Changes in nucleotide-related compounds in breast meat during aging at 0°C. ATP, adenosine triphosphate; ADP, adenosine diphosphate; AMP, adenosine monophosphate; IMP, inosine monophosphate; Hx, hypoxanthine

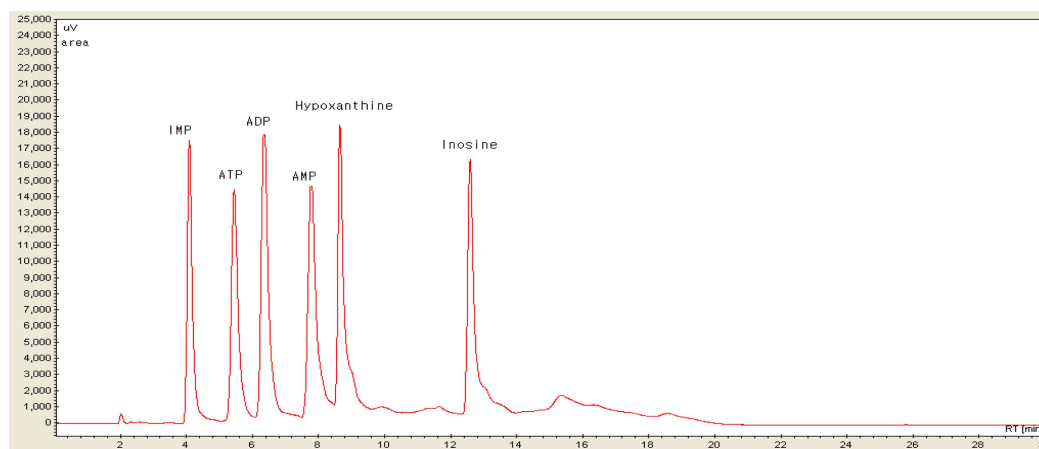
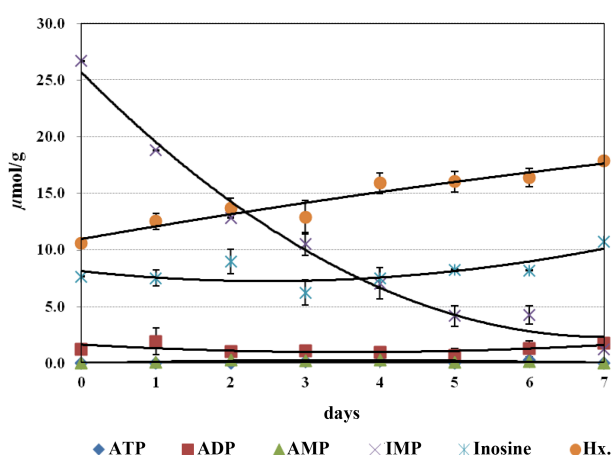


Fig. 1. High performance liquid chromatography chromatogram of nucleotide-related compound standard solutions. ATP, adenosine triphosphate; AMP, adenosine monophosphate; ADP, adenosine diphosphate; IMP, inosine monophosphate; Hx, hypoxanthine. HPLC conditions: Jasco PU-2089, column (Kromasil 100Å, 5 μm, C18), detector (Jasco UV-2075), Eluent A, ACN and eluent B, phosphate buffer (pH 7.00, 60 mM K<sub>2</sub>HPO<sub>4</sub>+40 mM KH<sub>2</sub>PO<sub>4</sub>). Gradient (0 min, 100% B; 4 min, 98% B; 5 min, 97% B; 8 min, 96% B; 15 min, 96% B; 15.01 min, 100% B), Flow rate (1 mL/min)



**Fig. 3. Changes in nucleotide-related compounds in leg meat during aging at 0°C.** ATP, adenosine triphosphate; ADP, adenosine diphosphate; AMP, adenosine monophosphate; IMP, inosine monophosphate; Hx, hypoxanthine

both less than those in breast meat. IMP, which affects umami taste reached its highest value on day 1 (29.17  $\mu\text{mol/g}$ ), and then decreased rapidly until day 7 with a value of 7.11  $\mu\text{mol/g}$ . Meinert *et al.* (2009) reported that IMP concentrations in pork loin decrease significantly during aging from 6.8  $\mu\text{mol/g}$  (day 4) to 4.0  $\mu\text{mol/g}$  (day 5). Inosine values in duck breast meat were 11.96-16.24  $\mu\text{mol/g}$  at 0°C, which were twice that of leg meat. At the same time, Hx content increased during the aging period to 7.86-14.93  $\mu\text{mol/g}$ .

ATP was not detected in leg meat during most of the aging period at 0°C (Fig. 3). Similar to the breast meat result, ATP, ADP and AMP contents did not change significantly during aging: 0.00-0.29  $\mu\text{mol/g}$  (ATP), 0.71-1.94  $\mu\text{mol/g}$  (ADP), 0.00-0.36  $\mu\text{mol/g}$  (AMP). Values of IMP and Hx were 18.81  $\mu\text{mol/g}$  and 12.55  $\mu\text{mol/g}$ , respectively, on day 1, whereas IMP decreased to 1.22  $\mu\text{mol/g}$  on day 7. It was concluded that the breakdown of IMP proceeded farther in leg meat than that in breast meat, as the gap in the IMP values between the early period and day 7 in leg meat was larger than that in breast meat. Tikki *et al.* (2006) reported that IMP content in pork decreases during aging, with a simultaneous result of an increase in inosine and Hx contents. However, Hong *et al.* (2004) reported that IMP in fish meat increased from 10-16  $\mu\text{mol/g}$  to 13-21  $\mu\text{mol/g}$  during aging. Sakaguchi *et al.* (1992) reported that IMP content does not always correspond with flavor; it is only a basic material that has a great influence on meat flavor.

These results suggest that nucleotide-related compounds were more decomposed in leg meat than those in breast meat. Ahn and Park (2002) reported similar results for

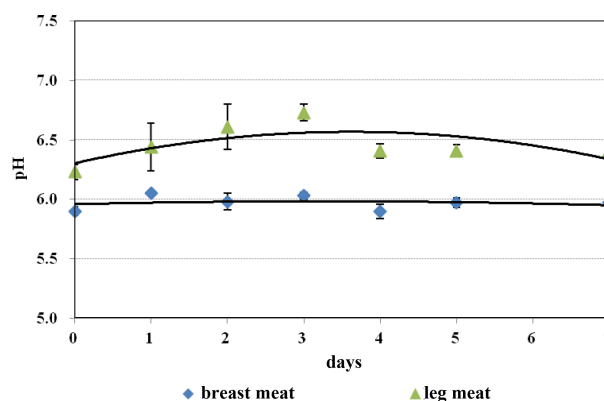
chicken meat. Liu *et al.* (2007) reported that inosine and umami contents in duck meat (aspartame and glutamic acid) increased during curing and roasting. Thus, further research is needed about the amino acids and peptides that influence meat flavor.

### pH changes

Fig. 4 shows the pH changes in the vacuum-packed duck breast and leg meat during aging at 0°C. The pH of breast meat during the early period was 5.90, and it did not change during aging (range, 5.90-6.05). The pH in leg meat during the early period was 6.23, which was higher than that of breast meat. pH seemed to increase until day 3 with values of 6.44-6.73, although it decreased to 6.41 after day 3. pH was higher in leg meat than that in breast meat during the entire aging period. Kang *et al.* (2006a) reported that pH changes depend on the deboning time, and that aging temperature does not significantly influence pH (range, 6.00-6.07). They also reported that pH changes in breast meat and leg meat according to the packaging method. Because of the exercise before slaughter, glycogen in the leg muscle is fully used; therefore, leg meat shows a higher pH content than that of breast meat. Rigor mortis of meat is related to various factors, including meat type, muscle type, nutrition level, aging temperature, and stress level during slaughter. The onset of rigor mortis differs depending on meat type: 6-12 h (beef), 1/2-3 h (pork), within 30 min (chicken), and within 1 h (fish). From these results, duck leg meat seemed to progress faster through the aging process than breast meat, as the pH increased until day 3 in leg meat whereas it changed little during that period in breast meat.

### VBN changes

Fig. 5 shows the VBN changes in duck breast and leg meat protein. VBN content was 9.30 mg% during the early



**Fig. 4. Changes in pH of duck meat during aging at 0°C.**

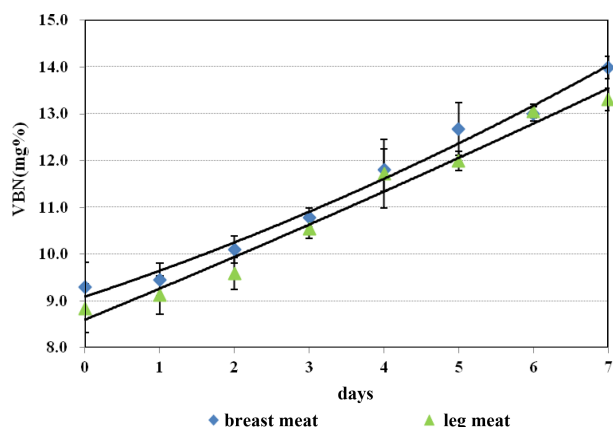


Fig. 5. Changes in volatile basic nitrogen (VBN) contents in duck meat during aging at 0°C.

period in breast meat. It was 10.09 mg% on day 2, 11.80 mg% on day 4, and 13.99 mg% on day 7. That is, VBN content increased during aging. The VBN content in leg meat also increased from 8.84 mg% during the early period, to 9.58 mg% on day 2, 11.72 mg% on day 4, and 13.31 mg% on day 7. This result agrees with the report by Cresopo *et al.* (1978) who stated that because part of the protein structure is cut off, nonprotein nitrogenous compounds such as free amino acids, nucleotide-related compounds, amines, ammonia, and creatine increase. They also reported that VBN content increased during aging. Dierick *et al.* (1974) reported that certain parts of meat that contain large amounts of protein and free amino acids have high VBN levels. According to SPISLP (2011), the amount of VBN is limited to 20 mg% for raw and packaged meat. Many meat products do not decay, though their VBN content is 30 mg%. In this study, VBN contents in breast and leg meat on day 7 were each 13.99 mg% and 13.31 mg%.

### Sensory evaluation

Flavor is an important sensory evaluation characteristic of cooked meat, as it is a comprehensive sense that integrates taste and smell (Seo and Yoo, 2010). Generally, fat, which becomes more available when meat is heated, causes distinct flavor depending on the meat type. While beef or pork can reveal their distinctive flavor without fat, it is essential for other meats have fat to reveal their flavors. Table 2 shows the changes in sensory characteristics of uncooked and cooked breast and leg duck meat during aging. Breast meat received the highest score for appearance of uncooked meat (8.2) on day 1, and received high scores (>7) throughout the aging period except on days 5 and 6. Leg meat also received a high score (8.6) on day 1,

but scores decreased as aging progressed. Scores for off-flavor of uncooked breast and leg meat appeared to increase as time passed. Finally, both breast and leg meat received the highest score (7.6) on day 1 for overall acceptance. Cooked breast meat received high scores for flavor and juiciness until days 2 and 3, and the overall acceptance score was the highest (7.6) on day 3. That is, the leg meat received the highest score on day 1 for flavor, juiciness, and overall acceptance, though the tenderness score was low.

Sakaguchi *et al.* (1992) reported that IMP content does not always correspond with flavor, as it is only a basic material that has a significant influence on meat flavor. Considering the result of nucleotide-related compounds in this study, the sensory evaluation results of leg meat corresponded with the nucleotide-related compounds results, as both IMP content and acceptance score were the highest on day 1. However, the acceptance score for breast meat was the highest on day 3, whereas IMP content was the highest on day 1; therefore, these results varied with meat type.

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