Taste-active compound levels in Korean native chicken meat: The effects of bird age and the cooking process

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ABSTRACT The effects of bird age and the cooking process on the levels of several taste-active compounds, including inosine 5′-monophosphate (IMP), glutamic acid, cysteine, reducing sugars, as well as oleic, linoleic, arachidonic, and docosahexaenoic acids (DHA), in the breast and leg meats from a certified meat-type commercial Korean native chicken (KNC) strain (*Woorimatdag*) were investigated. KNC cocks were raised under similar standard conditions at a commercial chicken farm, and breast and leg meats from birds of various ages (10, 11, 12, 13, and 14 wk; 10 birds/age group) were obtained. After raw and cooked meat samples were prepared, they were analyzed for the aforementioned taste-active compounds. Compared to the leg meat, KNC breast meat had higher levels of IMP, arachidonic acid, and DHA, but lower levels of the other taste-active compounds ($P < 0.05$). KNC meat lost significant amounts of all the taste-active compounds, excluding oleic and linoleic acids, during the cooking process ($P < 0.05$). However, bird age only had a minor effect on the levels of these taste-active compounds. The results of this study provide useful information regarding the levels of taste-active compounds in KNC meat from birds of different ages, and their fate during the cooking process. This information could be useful for selection and breeding programs, and for popularizing native chicken meat.

Key words: arachidonic acid, fatty acid, inosine 5′-monophosphate, umami taste

2015 Poultry Science 94:1964–1972
http://dx.doi.org/10.3382/ps/pev154

INTRODUCTION

With the aim of preventing the loss of endangered indigenous chicken breeds, the National Institute of Animal Science, Rural Development Administration of Korea developed a meat-type commercial Korean native chicken (**KNC**) strain (*Woorimatdag*) through a KNC breed restoration program (Jeon et al., 2010). This commercial KNC strain is characterized by having less fat and higher protein than exotic breeds (Jeon et al., 2010). Furthermore, KNC are highly preferred to commercial broilers by Korean consumers because of their unique flavor and texture (Jayasena et al., 2013b).

Flavor, which comprises mainly taste and aroma, is an important eating quality of meat (Sasaki et al., 2007; Jayasena et al., 2013a). Meat taste sensations primarily include saltiness, sweetness, sourness, and umami, and the major taste-active compounds in meat are amino acids, peptides, organic acids, nucleotides, and sugars (Liu et al., 2007; Sasaki et al., 2007).

Inosine 5′-monophosphate (**IMP**)—the predominant nucleotide in meat—and glutamic acid have vital contributions towards the development of umami taste in chicken meat (Fujimura et al., 1996; Liu et al., 2007; Sasaki et al., 2007; Jayasena et al., 2013a). Additionally, reducing sugars such as ribose and glucose have been shown to improve the taste of cooked meat by the formation of many important flavor compounds via the Maillard reaction (Aliani and Farmer, 2002; Meinert et al., 2009). For example, formation of 2-methyl-3-furanthiol—the most important chemical compound for chicken flavor development—involves the interaction between ribose and cysteine (Jayasena et al., 2013a). Notably, however, few studies have been conducted to date to determine sugar contents in chicken meat.

Several unsaturated fatty acids have also been proven to intensify the taste of meat. The primary oxidation products of linoleic acid (C18:2), such as hexanal and 2,4-decadienal, are the most abundant aldehydes implicated in chicken meat taste (Shi and Ho, 1994). Chicken meat containing higher levels of arachidonic

Received December 24, 2014.
Accepted April 20, 2015.
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acid (C20:4) displays better sensory attributes including umami (Jung et al., 2014; Kiyohara et al., 2011). Furthermore, Koriyama et al. (2002) demonstrated that docosahexaenoic acid (**DHA**; C22:6) suppresses sourness and bitterness, but increases sweetness and umami characteristics. Oleic acid (C18:1) is also considered to be a taste-related fatty acid in meat (Choe et al., 2010). Therefore, increasing the levels of these taste-active compounds in chicken meat may improve its sensory quality.

The concentration of taste-active compounds in chicken meat is known to be affected by a number of factors including the chicken breed/strain, diet of bird, and cooking (Jayasena et al., 2013a). As meat is generally consumed following cooking procedures, such treatment might be one of the most influential factors affecting the taste of meat. The effect of cooking on taste-active compounds of meat has been examined in only a few studies to date (Chikuni et al., 2002; Liu et al., 2007; Sasaki et al., 2007; Alfaia et al., 2010). Notably, quantitative studies of taste-active compounds in KNC meat have only been performed on raw meat (Ahn and Park, 2002; Choe et al., 2010; Jeon et al., 2010; Jayasena et al., 2013b); therefore, the effect of the cooking process on these compounds must be carried out in detail. In addition, information regarding the fate of these taste-active compounds in KNC meat from birds with increasing age is scarce.

Thus, in this study, we aimed to elucidate the effects of bird age and the cooking process on IMP, glutamic acid, cysteine, and reducing sugar contents, as well as on taste-related fatty acid composition in KNC breast and leg meats.

MATERIALS AND METHODS

All the experimental procedures conducted during this study followed the recommendations described in The Guide for the Care and Use of Laboratory Animals, published by the Institutional Animal Care and Use Committee of the National Institute of Animal Science (2012) in Korea.

Birds

During the study, KNC of a certified meat-type commercial strain (*Woorimatdag*) were raised under similar standard commercial conditions at a commercial chicken farm (Gimcheon, Korea). In addition, similar chicken care facilities and the procedures were carried out to meet or exceed the standards established by the Committee for Accreditation of Laboratory Animal Care at National Institute of Animal Science in Korea. A total of 160 one-day-old male chicks (*Woorimatdag*) obtained from a local hatchery were allotted to 5 floor pens (32 chicks/pen) within a single house. Chicks were fed commercial starter (3,100 kcal ME/kg, 23% CP during the first week), grower (3,200 kcal ME/kg, 20% CP from the second to third weeks), and finisher (3,200 kcal ME/kg, 18% CP from the fourth week to respective age) diets ad libitum, and had free access to water during the whole study period. The litter was checked and maintained daily and additional materials were added if the birds were slightly dirty. The birds had no access to the outdoor environment.

Processing

At each of the 5 ages investigated in this study (10, 11, 12, 13, and 14 wk), 2 KNC were randomly selected from each of the 5 pens (a total of 10 KNC from each age). After a 10-h feed-withdrawal period, KNC were exsanguinated by a conventional neck cut and were bled for 2 min. The carcasses were then manually defeathered and eviscerated, during which time the sex of each bird was confirmed to avoid any sex effect on the parameters tested in this study. The carcasses were chilled at 4°C for 24 h followed by vacuum-packing and storage in a freezer at −20°C until further analysis.

Raw and Cooked Sample Preparation

Frozen carcasses of each treatment were thawed in a refrigerator (4°C) for 24 h. Samples of the raw breast and leg meats were separately prepared by dissecting each muscle from the left half of each carcass. After trimming the visible skin, fat, and connective tissues, the raw meat samples were minced separately using a mini chopper (CH180, Kenwood, Shenzhen, China) and used for the subsequent analysis.

The remaining 10 halves from each treatment were used for the preparation of cooked meat samples. They were boiled separately in water (1:1.5 wt/vol) for 40 min until a core temperature of >72°C was reached, which represented the domestic boiling conditions for chicken meat. The temperature of the meat was measured by a digital thermometer (YF-160A Type-K, YFE, Hsinchu City, Taiwan). The carcasses were then vacuum-packed and cooled under running water. Finally, the cooked breast and leg meats from each half of the carcasses were dissected, deboned and minced separately, and then were used for the analysis.

IMP Content

The IMP content of each meat sample was measured according to the procedure of Jung et al. (2013). Briefly, the nucleic acids were extracted from the meat samples (5 g each) using 25 mL 0.7 M perchloric acid. The extract was then adjusted to pH 7 with 5 N KOH and brought to a final volume of 100 mL with 0.7 M perchloric acid (pH 7). After 30 min cooling, the mixture was centrifuged (Union 32R, Hanil Co. Ltd., Incheon, Korea) at 1,130 × *g* (4°C) and the supernatant was analyzed using an ACME-9000 HPLC system (Younglin Instruments Inc., Seoul, Korea) and a Waters–Atlantis

dC18 reverse-phase column (4.6 × 250 mm, 5 μm particles; Millipore Co-Operative, Milford, MA). The injection volume was 10 μL and elution time was 25 min, with a mobile phase of 0.1 M triethylamine in 0.15 M acetonitrile (pH 7.0) at an isocratic flow rate at 1.0 mL/min. The column temperature was maintained at 35°C, and the diode array detector (Younglin) was monitored at a wavelength of 260 nm. The quantity of IMP was calculated from a standard curve obtained using an IMP standard (Sigma–Aldrich Co., St. Louis, MO).

Taste-Related Fatty Acid Composition

Lipids were extracted from the meat samples using chloroform/methanol (2:1, vol/vol), according to the procedure of Folch et al. (1957). Fatty acid methyl esters were prepared from the extracted lipids using boron trifluoride (BF_3)–methanol (Sigma–Aldrich), followed by separation in a gas chromatograph (HP-7890, Agilent Technologies, Santa Clara, CA) with flame ionization detector (Agilent Technologies). A split inlet (split ratio, 100:1) was used to inject the samples into a capillary column (30 m × 0.32 mm; 0.25 μm; Omegawax 320, Supelco, Bellefonte, PA), and the sample components were separated using a ramped oven temperature (150°C for 5 min, temperature increased to 170°C at 5°C/min and maintained for 8 min, then increased to 190°C at 5°C/min and maintained for 15 min and finally increased to 220°C at 5°C/min, and maintained for 30 min). The inlet and detector temperature were 210 and 230°C, respectively. N_2 gas served as the carrier at a constant flow rate of 0.7 mL/min. Relative quantities were expressed as weight percent of total fatty acids identified via comparison of retention times to known standards (37 fatty acid methyl esters mix, conjugated linoleic acids mix, Sigma–Aldrich).

Glutamic Acid and Cysteine Content

Glutamic acid and cysteine contents were analyzed using the method of Hughes et al. (2002), with modification. Meat samples (5 g) were mixed with 20 mL 2% trichloroacetic acid and homogenized at 1,130 × *g* for 1 min [T25b, Ika Works (Asia), Sdn, Bhd, Malaysia]. The homogenate was centrifuged at 17,000 × *g* for 15 min (4°C; Hanil, Incheon, Korea) and filtered through a 0.45-μm membrane (Whatman International Ltd, Maidstone, England). The filtrate was derivatized using AccQ-Tag (Waters Corp., Milford, MA), according to the manufacturer's protocol, and 5 μL was injected into a reverse-phase HPLC system (3.9 × 150 mm; AccQ-Tag column, Waters) using a mobile phase consisting of buffers: A (Waters AccQ-Tag eluent) and B (60%, vol/vol, acetonitrile). The gradient flow rate at 1.0 mL/min was formed as follows: 0 min, 100% A, 0% B; 0.5 min, 98% A, 2% B; 15 min, 93% A, 7% B; 19 min, 90% A, 10% B; 32 min, 67% A, 33% B; 33 min, 67% A, 33% B; 34 min, 0% A, 100% B; 37 min, 0% A, 100% B; 38 min, 100% A, 0% B; and 45 min, 100% A, 0% B. The column temperature was 37°C and a Waters 2475 fluorescent detector was used with excitation and emission wavelengths of 250 and 395 nm, respectively. Individual amino acids were identified by comparison of their retention times with those of calibration standards (Sigma–Aldrich). Peak areas were calculated using Millennium 32 software, and the concentrations of glutamic acid and cysteine were expressed as mg/100 g fresh sample.

Reducing Sugar Content

Sugars were extracted from the meat samples (1 g) twice using 5 mL hot 80% ethanol (50°C) per extraction. The extracts were then centrifuged at 1,130 × *g* for 10 min (4°C; Hanil), and the supernatants were filtered (filter paper No. 1, Whatman International Ltd) separately into 15-mL tubes and evaporated using N_2 gas (99.999%). The dried sugars were dissolved in distilled water (2 mL), and this solution was centrifuged at 10,000 × *g* for 10 min (4°C; HM-150IV, Hanil). Subsequently, the reducing sugar content of each extract was measured by dinitrosalicylic acid method, as described by the Korea Society of Food Science and Nutrition (2000). Briefly, 1 mL each extract was mixed with 2 mL dinitrosalicylic solution (0.5 g dinitrosalicylic acid, 8.0 g NaOH, and 150 g Rochelle salt in 500 mL distilled water) in a 15-mL test tube and heated in a water bath (90°C) for 10 min. The mixture was then cooled under running water for 5 min and the absorbance was measured at 550 nm using a spectrophotometer (DU 530, Beckman Coulter, Inc., Brea, CA). Finally, the amount of reducing sugar in each sample was calculated from a standard curve produced using a glucose standard (Sigma–Aldrich), and expressed as a percentage (wt/wt) of the fresh raw meat sample.

Statistical Analysis

The data of the birds from the same pen were averaged for each parameter. The effects of cooking, the meat cut, and the age of the KNC were estimated using 3-way factorial ANOVA and the GLM procedure within a completely randomized design. After grouping the data by each state of meat (raw or cooked) with each meat cut, the data were analyzed by 1-way ANOVA and the GLM to confirm the associations and effects of the meat cut, state of meat, and age. Mean separation was conducted using Tukey's multiple range test ($P < 0.05$). The mean values and SEM were reported. The software of SAS (2011) (version 9.3, Cary, NC) was used for all statistical analyses.

RESULTS AND DISCUSSION

Umami-Related Compound Content

Table 1 shows the IMP and glutamic acid contents of KNC breast and leg meats, before and after cooking. According to the pooled data, the IMP content in KNC meat depended on the following factors, in order of significance: the meat cut (breast or leg meat), cooking status, and bird age. In addition to the main effects, the higher order interaction (meat cut × cooking × age) and all possible lower-order interactions had a significant effect on IMP content ($P < 0.05$; data not shown). In contrast, the cooking process was shown to have the most significant effect on the glutamic acid content of KNC meat, followed by the meat cut and age of the bird (Table 1). Furthermore, all possible lower order interactions significantly influenced the abundance of glutamic acids in KNC meat (data not shown).

For all age groups, the breast meat showed significantly higher IMP content compared to that of the leg meat, in both raw and cooked states (Table 1). This result was in agreement with previous findings reported by several researchers (Ahn and Park, 2002; Jung et al., 2013; Jayasena et al., 2014). The observed difference in IMP content may be explained by the distinct composition of muscle fibers in these 2 muscles (Jaturasitha et al., 2008). Jung et al. (2013) reported that breast meat is composed of more than 90% Type IIB muscle fibers (white fibers), whereas leg meat is mainly composed of Type I muscle fibers (red fibers). Arabadjis et al. (1993) demonstrated that Type II muscle fibers exhibit higher accumulation of IMP than do Type I muscle fibers in rat skeletal muscle. Furthermore, Type I muscle fibers exhibit greater 5′-nucleotidase activity—the enzyme that catalyzes the degradation of IMP to inosine—compared to Type II muscle fibers in rat skeletal muscle (Tullson and Terjung, 1999).

The content of IMP in meat was previously reported to increase with increasing bird age (Chow and Jacobson, 1968; Rikimaru and Takahashi, 2010). A similar tendency was observed in raw breast meat in the present study (Table 1); raw KNC breast meat from 13-week-old birds had significantly higher IMP content than that of 10- and 11-week-old birds, but levels comparable to that of 12- and 14-week-old birds. In contrast, the IMP contents of raw leg meat and cooked meat fluctuated ($P < 0.05$) with increasing bird age. The IMP content was greater ($P < 0.05$) in raw KNC leg meat from 12-week-old birds than in that of the other age groups. Similar age-dependent variations in IMP levels in KNC raw leg meat have been reported previously (Ahn and Park, 2002). However, comparable results have not been reported for the IMP content in cooked meat from indigenous chickens of varying age.

Cooking depleted the IMP and glutamic acid contents of meat, irrespective of the age of the bird and meat cut ($P < 0.05$; Table 1). Raw meat had significantly higher IMP and glutamic acid levels (average 243.38 mg/100 g and 32.52 mg/100 g, respectively) than cooked meat (average 110.50 mg/100 g and 22.36 mg/100 g, respectively). Similar losses in these umami-related compounds have been reported in cooked pork (Chikuni et al., 2002; Sasaki et al., 2007), duck meat (Liu et al., 2007), and cooked chicken meat (Jayasena et al., 2014). These observed losses might be attributed to: 1) leaching of these compounds from muscles into cooking juice, owing to their high water solubility (Sasaki et al., 2007); 2) thermal degradation of IMP into inosine and hypoxanthine (Kavitha and Modi, 2007); 3) reaction of IMP with cysteine during cooking (Shi and Ho, 1994); and 4) reaction of glutamic acid with inosinic acid, resulting in umami notes in meat (Jo et al., 2012).

The difference in glutamic acid content between KNC breast and leg meat was more clear-cut (Table 1); the leg meat had markedly higher glutamic acid content (average 30.53 mg/100 g) than the breast meat (average 24.35 mg/100 g). These data agree well with previously reported glutamic acid contents in indigenous chicken meats (Ahn and Park, 2002; Wattanachant et al., 2004). Rikimaru and Takahashi (2010) and Chae et al. (2012) showed that glutamic acid content in meat decreases with increasing age of the chicken. A similar decrease was identified in raw leg meat in the present study. The glutamic acid content in the raw KNC breast meat varied as the age of the bird increased. While increasing bird age had no effect ($P > 0.05$) on the glutamic acid content of cooked leg meat, it positively affected ($P < 0.05$) glutamic acid levels in cooked breast meat. Therefore, we propose that the effect of age on IMP and glutamic acid contents in meat depends on the meat cut and cooking status.

Cysteine Content

The cysteine contents in raw and cooked KNC breast and leg meat from birds of varying ages are given in Table 2. According to the pooled data, the cysteine content was affected, in order of significance, by cooking, the age of the bird, and meat cut. Furthermore, there were lower order interactions (cooking × age and meat cut × cooking) influencing the cysteine content of KNC meat ($P < 0.05$; data not shown). Cysteine was most predominant in the raw meat (Table 2; $P < 0.05$), with the average contents in raw and cooked meat being 3.49 mg/100 g and 1.71 mg/100 g, respectively (data not shown). Similar results were reported by Liu et al. (2007) and Jayasena et al. (2014) who showed that raw duck and chicken meat had substantially higher cysteine content than their respective cooked forms. The decrease in cysteine content after cooking is related to the formation of volatile compounds (Liu et al., 2007). Jayasena et al. (2013a) reported that 2-methyl-3-furanthiol—the compound responsible for the meaty flavor of chicken broth—is formed by the reaction of cysteine with reducing sugars or IMP during cooking.

Table 1. Umami-related compound content (mg/100 g) of the raw and cooked meat from Korean native chickens at different ages (n = 5).

Item (mg/100 g)	Age (wk)	Raw meat		SEM	Cooked meat		SEM	Analyzed value		
		Breast	Leg		Breast	Leg		Meat cut	Cooking	Age
Inosine-5′-monophosphate	10	$350.84^{b,x}$	$130.71^{b,y}$	9.08	$161.83^{b,x}$	$73.27^{a,y}$	7.38			
	11	$244.47^{c,x}$	$129.48^{b,y}$	7.88	$115.07^{c,x}$	$61.51^{a,b,y}$	9.77			
	12	$377.56^{a,b,x}$	$157.22^{a,y}$	17.36	$207.82^{a,x}$	$67.70^{a,b,y}$	8.56			
	13	$403.81^{a,x}$	$134.54^{b,y}$	9.64	$168.28^{b,x}$	$55.56^{b,c,y}$	5.97			
	14	$379.49^{a,b,x}$	$125.68^{b,y}$	14.88	$149.42^{b,x}$	$44.52^{c,y}$	7.93			
	SEM	15.83	7.31		10.41	4.50				
	P-value							< 0.0001	< 0.0001	< 0.0001
	F-value							1150.77	815.63	22.14
Glutamic acid	10	$29.94^{b,y}$	$45.45^{a,x}$	1.26	$16.73^{b,y}$	22.64^{x}	1.51			
	11	$34.53^{a,y}$	$38.49^{b,x}$	1.16	$22.42^{a,y}$	27.13^{x}	1.47			
	12	$25.29^{c,d,y}$	$37.63^{b,x}$	1.61	$20.58^{a,y}$	25.23^{x}	1.43			
	13	$22.71^{d,y}$	$30.79^{c,x}$	1.61	22.18^{a}	23.37	2.13			
	14	$28.51^{b,c}$	31.83^{c}	1.27	20.63^{a}	22.70	1.80			
	SEM	1.36	1.41		1.16	2.09				
	P-value							< 0.0001	< 0.0001	< 0.0001
	F-value							78.98	213.71	8.80

[a–d]Mean values in the same column with different superscripts within the same compound differ significantly ($P < 0.05$).
[x,y]Mean values in the same row with different superscripts within the same state of meat differ significantly ($P < 0.05$).

Table 2. Cysteine content (mg/100 g) of the raw and cooked meat from Korean native chickens at different ages (n = 5).

Item (mg/ 100 g)	Raw meat		SEM	Cooked meat		SEM	Analyzed value		
	Breast	Leg		Breast	Leg		Meat cut	Cooking	Age
Age (wk)									
10	$4.31^{a,x}$	$3.57^{a,y}$	0.17	$1.18^{b,y}$	$3.63^{a,x}$	0.41			
11	$3.79^{a,b,x}$	$3.24^{a,b,y}$	0.16	$0.00^{c,y}$	$3.38^{a,x}$	1.01			
12	3.62^{b}	$3.24^{a,b}$	0.27	$3.22^{a,y}$	$4.82^{a,x}$	0.28			
13	$3.79^{a,b,x}$	$3.24^{a,b,y}$	0.17	$0.00^{c,y}$	$0.86^{b,x}$	0.21			
14	3.25^{b}	2.87^{b}	0.23	0.00^{c}	0.00^{b}	0.00			
SEM	0.19	0.21		0.16	0.75				
P-value							0.0050	< 0.0001	< 0.0001
F-value							8.09	78.61	15.04

[a–c]Mean values in the same column with different superscripts differ significantly ($P < 0.05$).
[x,y]Mean values in the same row with different superscripts within the same state of meat differ significantly ($P < 0.05$).

Furthermore, cysteine thiol groups can be oxidized during cooking, leading to the formation of dimethyl disulfide compounds (Toldrá et al., 2000). Bæch et al. (2003) showed that the cysteine content of meat decreases with increasing cooking temperature.

The age of the bird had a marked effect on the cysteine content in KNC meat (Table 2). The cysteine contents of raw and cooked KNC leg meats and raw breast meat decreased with increasing bird age; 10-week-old birds showed the highest level of cysteine in both raw breast and leg meats. In contrast, comparable cysteine contents are observed in broiler meat, irrespective of the age of the bird or meat cut (Chae et al., 2012). These contradictory results might be attributed to breed effect and the different experimental conditions under which the two studies were performed, including the birds' diet. The effect of meat cut on cysteine content in KNC meat was significant (Table 2); the breast and leg meats showed average cysteine contents of 2.32 mg/100 g and 2.88 mg/100 g, respectively (data not shown). Similarly, Chae et al. (2012) found greater cysteine levels in raw leg meat from broiler chickens than that in breast meat. In contrast, we detected a higher level of cysteine in KNC breast meat compared to that in leg meat in their raw state ($P < 0.05$), except in birds between 12- and 14-week-old.

Reducing Sugar Content

Table 3 shows the reducing sugar contents of breast and leg KNC meats, as affected by bird age and cooking status. The reducing sugar content was affected by all three factors tested ($P < 0.05$), in the following order of significance: cooking status, meat cut, and bird age. In addition, 2 lower-order interactions (cooking × age and meat cut × cooking) were detected that affect the reducing sugar content ($P < 0.05$; data not shown). The reducing sugar content was significantly decreased by the cooking process in both meat cuts from birds at any given age; the average reducing sugar contents of raw and cooked meats were 0.14 and 0.04%,

Table 3. Reducing sugar content (%) of the raw and cooked meat from Korean native chickens at different ages (n = 5).

	Raw meat			Cooked meat			Analyzed value		
Item (% glucose)	Breast	Leg	SEM	Breast	Leg	SEM	Meat cut	Cooking	Age
Age (wk)									
10	$0.146^{a,y}$	$0.217^{a,x}$	0.008	$0.040^{a,b}$	0.041^{c}	0.002			
11	$0.095^{b,c,y}$	$0.180^{b,x}$	0.010	0.034^{b}	0.042^{c}	0.003			
12	$0.101^{b,c,y}$	$0.161^{b,x}$	0.011	$0.041^{a,b}$	$0.048^{b,c}$	0.003			
13	$0.085^{c,y}$	$0.146^{b,x}$	0.001	$0.037^{b,y}$	$0.059^{a,b,x}$	0.005			
14	$0.111^{b,y}$	$0.144^{b,x}$	0.010	$0.045^{a,y}$	$0.066^{a,x}$	0.004			
SEM	0.007	0.012		0.002	0.004				
P-value							< 0.0001	< 0.0001	< 0.0001
F-value							29.95	726.62	9.58

[a–c]Mean values in the same column with different superscripts differ significantly ($P < 0.05$).

[x,y]Mean values in the same row with different superscripts within the same state of meat differ significantly ($P < 0.05$).

respectively (data not shown). The average reducing sugar content of raw KNC meat was comparable to that of a commercial chicken breed reported by Aliani and Farmer (2002). In agreement with our findings, Liao et al. (2010) and Jayasena et al. (2014) reported that the glucose contents of chicken and duck meats and the reducing sugar content of chicken meat decreased during cooking, respectively. The changes in reducing sugar content caused by the cooking process can be attributed to: 1) the involvement of sugars in the Maillard reaction, which generates degradation products responsible for the formation of heterocyclic compounds; and 2) the alteration or degradation of ribose, the most heat-labile sugar, under high-temperature conditions (Shi and Ho, 1994; Liao et al., 2010; Jayasena et al., 2013a; Williamson et al., 2014).

Significantly higher reducing sugar contents were found in KNC leg meat than in breast meat, which had average values of 0.11 and 0.07%, respectively (data not shown). This is in agreement with the recent findings of Jayasena et al. (2014). Higher reducing sugar content in leg meat might be attributable to the higher level of IMP degradation in leg muscle than in the breast (Tullson and Terjung, 1999). In contrast, Aliani and Farmer (2002) observed that breast meat contained significantly more ribose and glucose than leg meat from a commercial chicken breed. Bird age showed a significant, but variable effect on the reducing sugar content of KNC meat. In general, the reducing sugar content of raw meat decreased with increasing KNC age; 10-week-old birds had the highest reducing sugar contents in both meat cuts. However, no difference in reducing sugar content in raw KNC leg meat was observed in birds after 11 wk age. In cooked KNC leg meat, bird age had a positive relationship ($P < 0.05$) with the reducing sugar content, whereas the reducing sugar content of cooked breast meat varied ($P < 0.05$) with increasing bird age. To our knowledge, this is the first report on reducing sugar content in chicken or any other meat as a function of age.

Taste-Related Fatty Acid Composition

Taste-related fatty acid composition of KNC meat, as affected by the age of the bird, meat cut, and cooking status is listed in Table 4. According to the pooled data, all three factors significantly affected the composition of taste-related fatty acids (Table 4). In order of significance, the arachidonic acid and DHA percentages were affected ($P < 0.05$) by the meat cut, cooking status, and bird age. In contrast, cooking had the greatest effect on oleic acid composition, followed by the meat cut and bird age ($P < 0.05$). Furthermore, the higher-order interaction or any lower-order interaction was not significant for any of the taste-related fatty acids ($P > 0.05$), except DHA. In this regards, the higher order interaction (meat cut × cooking × age) and the lower order interaction between meat cut and cooking influenced the availability of DHA in KNC meat ($P < 0.05$; data not shown).

The oleic acid percentage was significantly higher in cooked meat (average of 27.90%) compared to that in raw meat (average of 23.40%). In contrast, the arachidonic acid and DHA levels decreased as a result of the cooking process; raw meat had average values of 10.30 and 4.06%, whereas cooked meat contained average values of 6.92 and 2.56%, respectively. These respective changes in taste-related fatty acid composition were observed in both meat cuts and in all age groups (Table 4). Similar variations in taste-active fatty acid profiles have been reported for cooked chicken patties (Echarte et al., 2003), beef (Alfaia et al., 2010), and chicken meat (Jayasena et al., 2014). The observed reductions in the unsaturated fatty acids arachidonic acid and DHA are likely attributable to their higher susceptibility to undergo oxidative degradation compared to oleic and linoleic acids under high-temperature cooking conditions (Alfaia et al., 2010).

Table 4 shows that the percentages of oleic and linoleic acids were higher ($P < 0.05$) in KNC leg meat (average of 27.65 and 27.10%, respectively) than in breast meat (average 23.64 and 21.64%, respectively).

Table 4. Taste-related fatty acid composition (%) of the raw and cooked meat from Korean native chickens at different ages (n = 5).

		Raw meat			Cooked meat			Analyzed value		
Item (%)	Age (wk)	Breast	Leg	SEM	Breast	Leg	SEM	Meat cut	Cooking	Age
Oleic acid	10	20.33^{y}	24.71^{a,b,x}	0.95	23.84^{y}	29.00^{x}	0.67			
	11	21.07^{y}	26.14^{a,x}	0.92	26.76	30.14	1.26			
	12	21.59^{y}	25.32^{a,b,x}	1.00	26.70	33.11	2.34			
	13	22.73^{y}	26.82^{a,x}	0.51	25.78^{y}	29.33^{x}	0.92			
	14	22.43	22.88^{b}	1.08	25.20^{y}	29.10^{x}	0.81			
	SEM	0.91	0.93		1.04	1.59				
	P-value							< 0.0001	< 0.0001	0.0160
	F-value							60.28	75.66	3.32
Linoleic acid	10	20.70^{y}	26.40^{a,b,x}	0.68	21.25^{b,y}	27.17^{x}	0.90			
	11	21.42^{y}	25.30^{b,x}	0.88	22.35^{a,b,y}	25.84^{x}	0.74			
	12	22.06^{y}	28.00^{a,x}	0.71	24.02^{a}	27.24	0.95			
	13	19.98^{y}	27.67^{a,b,x}	0.53	22.49^{a,b,y}	28.18^{x}	0.40			
	14	20.26^{y}	27.26^{a,b,x}	1.15	21.87^{a,b,y}	27.93^{x}	0.99			
	SEM	0.86	0.79		0.74	0.90				
	P-value							< 0.0001	0.0147	0.0616
	F-value							219.17	6.31	2.38
Arachidonic acid	10	13.68^{x}	8.23^{a,b,y}	0.83	10.88^{a,x}	5.25^{a,y}	0.52			
	11	12.03^{x}	7.40^{a,b,y}	0.50	8.43^{a,b,x}	4.67^{a,b,y}	0.81			
	12	12.55^{x}	6.80^{a,b,y}	0.77	7.82^{b,x}	3.40^{b,y}	0.98			
	13	13.05^{x}	6.10^{b,y}	0.40	9.35^{a,b,x}	4.46^{a,b,y}	0.49			
	14	14.34^{x}	8.86^{a,y}	1.02	10.43^{a,b,x}	4.55^{a,b,y}	0.55			
	SEM	0.82	0.66		0.89	0.43				
	P-value							< 0.0001	< 0.0001	0.0006
	F-value							267.95	109.51	5.73
DHA	10	6.31^{a,x}	2.82^{a,b,y}	0.33	4.49^{a,x}	1.66^{a,y}	0.26			
	11	5.25^{a,b,x}	2.26^{a,b,y}	0.18	3.02^{b,c,x}	1.33^{a,b,y}	0.34			
	12	5.83^{a,b,x}	2.03^{b,y}	0.43	2.82^{c,x}	0.96^{b,y}	0.40			
	13	5.82^{a,b,x}	2.37^{a,b,y}	0.41	4.18^{a,b,x}	1.60^{a,y}	0.27			
	14	4.60^{b}	3.31^{a}	0.51	3.98^{a,b,c,x}	1.58^{a,y}	0.19			
	SEM	0.45	0.32		0.40	0.15				
	P-value							< 0.0001	< 0.0001	0.0024
	F-value							281.13	90.93	4.67

$^{a–c}$Mean values in the same column with different superscripts within the same compound differ significantly ($P < 0.05$).
^{x,y}Mean values in the same row with different superscripts within the same state of meat differ significantly ($P < 0.05$).

In contrast, breast meat had significantly higher levels of arachidonic acid and DHA (average 11.26 and 4.63%, respectively) compared to leg meat (average 5.97 and 1.99%, respectively). A similar trend has been observed in previous comparisons of fatty acid compositions in breast and leg meats (Jeon et al., 2010; Jayasena et al., 2013b; Jayasena et al., 2014).

No significant differences in the oleic, linoleic, and arachidonic acid percentages were detected in raw KNC breast meat from the different age groups, whereas DHA levels differed. As the bird age increased, the DHA level of raw KNC breast meat decreased, particularly after 13 wk age. Furthermore, the percentage of oleic acid in raw leg meat decreased with increasing KNC age, especially after 13 wk age ($P < 0.05$). Similarly, arachidonic acid and DHA levels in raw leg meat decreased significantly up to 13 wk age, and then increased again. Contrary to the results of the present study, Chae et al. (2012) observed increases in the levels of linoleic and arachidonic acids, and DHA in raw breast meat, but similar levels in raw leg meat from broiler chickens when their age was increased from 30 to 42 d. In the same study, oleic acid levels in raw breast and leg meats decreased with increasing bird age. Nevertheless, the comparison of results is difficult as fatty acid compositions are also influenced by breed, feeding, and slaughter age (Orellana et al., 2009). The age of the bird showed no effect ($P > 0.05$) on the percentage of oleic acid in cooked KNC breast and leg meat or the linoleic acid level in cooked leg meat. The arachidonic acid percentage in cooked meat was different ($P < 0.05$) only in birds between 10 and 12 wk age. Additionally, the DHA levels in cooked meat significantly decreased up to 12 wk age, and then increased again ($P < 0.05$).

In summary, all the taste-active compounds tested in the present study were affected by cooking, the meat cut, and KNC age ($P < 0.05$). Compared with breast meat, the KNC leg meat had significantly higher contents of glutamic acid, cysteine, reducing sugars, and oleic and linoleic acids, but lower amounts of IMP, arachidonic acids, and DHA. Depletion of all the taste-active compounds tested, excluding oleic and linoleic acids, occurred during the cooking process, which was primarily due to their higher water solubility and conversion of these precursors into taste compounds. In contrast, the effect of bird age on the contents of these

compounds did not show a consistent trend in KNC meat. Further studies are being conducted to compare the levels of these taste-active compounds in KNC meat with those in the meat of other commercial broilers.

ACKNOWLEDGMENTS

This study was supported by Golden Seed Project, Ministry of Agriculture, Food, and Rural Affairs; Ministry of Oceans and Fisheries; Rural Development Administration; and Korea Forest Services and Institute of Green Bio Science and Technology, Seoul National University.

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