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ARTICLE

Comparison of Bioactive Compounds and Quality Traits of Breast Meat from Korean Native Ducks and Commercial Ducks

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Abstract

The aim of this research was to compare the bioactive compound content and quality traits of breast meat from male and female Korean native ducks (KND) and commercial ducks (CD, Cherry Valley). Meat from three 6-wk old birds of each sex from KND and CD were evaluated for carcass and breast weights, pH, color, cooking loss, shear force, and bioactive compound (creatine, carnosine, anserine, betaine, and L-carnitine) content. KND showed significantly higher carcass weights than CD whereas no such difference (p>0.05) was found between male and female ducks. The breed and sex had no significant effects on the breast weight, pH value, and shear force. However, KND had significantly lower cooking loss values than did CD. Creatine, anserine, and L-carnitine contents were significantly higher in KND than in CD and were predominant in female ducks compared to males. The results of this study provide rare information regarding the amounts and the determinants of several bioactive compounds in duck meat, which can be useful for selection and breeding programs, and for popularizing indigenous duck meat.

Key words: meat quality traits, bioactive compounds, commercial duck, Korean native duck

Introduction

Meat and meat products are excellent sources for proteins, vitamins such as B_{12}, and minerals (Jimenze-Colmenero *et al*., 2001), however, their risk related to cardiovascular diseases and colon and other cancers has also been reported (Kim *et al*., 2013; McAfee *et al*., 2010; Oostindjer *et al*., 2014), making consumers more concerned about meat consumption. As consumers understand more that food consumption is one of the important factors and can influence on human health (Goetzke, 2014; Lähteenmäki, 2013), consuming meat and meat products on our meal has been a controversial issue with their benefit and risk. Meanwhile, duck meat consumption in Korea has been increased approximately by 5-folds from 1997 to 2012 (Korea Duck Association, 2013), which might be attributable to consumers' increasing concern about the consumption of healthier meat. Duck meat is considered to be healthier compared to other animal products as it contains higher unsaturated fatty acid, essential fatty acid, and protein contents, in addition to its ability to decrease LDL cholesterol and blood pressure (Heo *et al*., 2013; Kim *et al*., 2010a).

With the increase in duck meat consumption, considerable efforts have been made since 1990's to popularize duck meat as a healthier meat source to secure the competitiveness in world market. The present Korean native duck (KND) produced by National Institute of Animal Science (NIAS) is a crossbreed between mallard duck (*Anas platyrhynchos*) and meat-type duck (Kim *et al*., 2010a; Kim *et al.,* 2010b). However, still 90% of the breeding ducks in Korea are the breeds from oversea such as Cherry Valley (England) and Grimaud (France) and only 10% of them are KND (Kim *et al*., 2012a). Hence, it is an urgent goal to preserve pure bloodlines and develop a commercial meat-type KND breed by utilizing indige-

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nous breeds such as Woorimatori™ [developing Korean indigenous breed by National Institute of Animal Science (NIAS), RDA, Korea] to meet the increasing demand for duck meat. In developing a meat-type KND breed, it is important to carry out more investigations on quality traits of duck meat. When the present KND is further improved, it may have a possibility to secure the competitiveness against other breeds or animal products.

Designing meat and meat products as functional foods has received more attention in the field of meat technology. Functional foods with beneficial impact on health (Goetzke *et al*., 2014) have become a worldwide trend and a craving for healthier food, and its market is continuously expanding based on increasing consumption and interest. Jimenez-Colmenero *et al*. (2001) and Olmedilla-Alonso *et al*. (2013) agreed on an optimistic prediction for improving nutritional value and positive image of meat and meat products when they are developed as functional foods. In this regards, improving the bioactive compound content in meat and meat products can be an effective mean. Important bioactive compounds in meat include coenzyme Q_{10}, taurine, conjugated linoleic acid, glutathione, lipolic acid, betaine, L-carnitine, creatine, carnosine, and anserine. They are abundant in mammalian skeletal muscles and have distinct biological functions in animal body, including working as a pH buffer, effective antioxidative and anti-aging agent, and an osmolyte. (de Zwart *et al*., 2003; Hipkiss, 1998; Schmid, 2009; Stenesh and Winnick, 1960).

During the development of KND, most of studies on duck meat were focused on productive aspect and basic quality traits (Heo *et al*., 2013; Kim *et al*., 2010a; Kim *et al.,* 2010b; Kim *et al*., 2012a) rather than its functional properties. Research findings on the availability and amounts of bioactive compounds in duck meat, in particular KND meat, are scarce. Therefore, the aim of this research was to compare the bioactive compound content and other quality traits of the breast meat from KND and commercial ducks (CD). In addition, the effect of sex on the same parameters was tested.

Materials and Methods

Sample preparation

Frozen carcasses from three birds of each sex from different breeds, KND and CD (Cherry Valley), were purchased at 6 wk of age from a local farm (Korea), and transported in frozen condition to a laboratory. Then, the carcasses were thawed at 4°C for 48 h, deskinned, and deboned manually. After collecting breast meat from each carcass, they were minced separately using a mini chopper (CH180, Kenwood, China) for 30 sec and used for the analysis. The carcass and breast weights (g) from each bird were also recorded.

pH

Each meat sample (1 g) was homogenized with 9 mL of distilled water using a homogenizer (T10 basic, Ika Works, Germany). The homogenates were centrifuged (Union 32R, Hanil Co., Ltd., Korea) at 3,000 rpm for 10 min and filtered (Whatman No. 4, Whatman PLC., UK). The pH value of each filtrate was measured using a pH meter (SevenGo, Mettler-Toledo International Inc. Switzerland) which was pre-calibrated using standard buffers (pH 4.01, 7.00, and 9.21).

Cooking loss

Cooking loss was determined as the percentage weight loss of each meat sample after cooking. Meat samples (30 g) were vacuum packed (HFV-600L, Hankook Fujee Co., Ltd., Korea), heated in a water bath at 90°C for 15 min until a core temperature of 72°C was reached, and cooled in iced water. After recording the final weight, cooking loss was calculated as expressed below:

$$\text{Cooking loss (\%)} = \frac{\textit{Weight before cooking} - \textit{Weight after cooking}}{\textit{Weight before cooking}} \times 100$$

Shear force

Cooked sample was cut into a 10 × 10 × 30 mm to measure shear force. The value was measured using a Warner-Bratzler shear attachment on a texture analyzer (CT3 10K, Brookfield Engineering Laboratories., USA) with a maximum cell load, 10 kg; target load, 10 g; target value, 25 mm; target speed 2.0 mm/sec. The samples were sheared perpendicularly to the direction of muscle fiber.

Meat color

The surface color measurements (CIE L*, a*, and b* values representing lightness, redness, and yellowness, respectively) of meat samples were measured using a colorimeter (CR-310, Minolta Co., Ltd., Japan) which was calibrated against a white reference tile (Minolta calibration plate, No. 14633072). Three observation readings were taken for each color measurement in order to minimize the possible errors and the average was used as one

replicate.

Creatine, anserine, and carnosine contents

The creatine, anserine, and carnosine contents in the samples were determined as described by Mora *et al*. (2007). Minced meat sample (2.5 g) were homogenized (T10 basic, Ika Works) with 7.5 mL of 0.01 N HCl at 13,500 rpm for 1 min. The homogenate was centrifuged at 3,000 rpm for 30 min (Union 32R, Hanil Co., Ltd., Korea), and 1 mL of the supernatant was transferred into a microtube and centrifuged at 10,000 rpm for 10 min (HM-150IV, Hanil). After centrifugation, 0.5 mL of the supernatant was mixed with 1.5 mL of acetonitrile, and the mixture was centrifuged at 10,000 rpm for 10 min (HM-150IV, Hanil), and the supernatant was filtered through a membrane filter (0.2 μm) into a glass vial. The samples were injected into a high performance liquid chromatography (HPLC; Ultimate 3000, Thermo Fisher Scientific Inc., USA) system under the gradient condition of two mobile phases; mobile phase A was 0.65 mM ammonium acetate in distilled water and acetonitrile (25:75 v/v, pH 5.5), and mobile phase B was 4.55 mM ammonium acetate in distilled water and acetonitrile (70:30 v/v, pH 5.5). The analytical conditions for HPLC was set up as descri- bed: injection volume, 10 μL; column, Atlantis HILIC silica column, 4.6 × 150 mm, 3 μm (Waters Corp., USA); flow rate, 1.2 mL/min. A detector was used at 214 nm to determine the creatine, anserine, and carnosine contents. The contents of the compounds were calculated using a standard curve obtained from the standard (Sigma, USA) of each compound.

Betaine and L-carnitine contents

The betaine and L-carnitine contents were quantified following the modified method of Jayasena *et al*. (2014a). Five grams of each meat sample was added with 10 mL of acetonitrile-methanol (9:1) solution and homogenized (T10 basic, Ika Works) at 13,500 rpm for 30 s. The homogenate was then centrifuged at 3,100 rpm for 5 min at 4ºC (Union 32R, Hanil), and the supernatant was filtered into a 20-mL volumetric flask through a funnel plugged with glass wool. The remaining filtrate was again mixed with 10 mL of acetonitrile-methanol solution and centrifuged (Union 32R, Hanil) under the same conditions. The resulting supernatant was collected in the same volumetric flask which was then filled with acetonitrile-methanol solution. Subsequently, 2 mL of this sample was transferred to a 15-mL tube and then 810 mg of Na_2HPO_4 and 90 mg of Ag_2O (9:1 w/w) were added. After vortex-mixing the solution, the sample tubes were dried by shaking without their caps in a shaking machine for 20 min and then centrifuged at 3,100 rpm for 5 min (Union 32R, Hanil, Korea). A 0.5-mL aliquot of each supernatant sample was then mixed with 0.5 mL of derivative reagent (0.066 g of 18-crown-6 and 1.39 g of bromoacetophenone in 100 mL of acetonitrile) in a 15-mL tube, voltexed, and heated in a water bath at 80ºC for 60 min. After cooling under running water, this mixture was filtered through a membrane filter (0.2 μm) and analyzed in a HPLC system (Ultimate 3000, Thermo Fisher Scientific Inc., USA) to determine betaine and L-carnitine contents. Two mobile phases (A, 25 mM ammonium acetate in which pH was adjusted to 3.0 using formic acid; B, acetonitrile) were used and the analytical condition for HPLC was set up as described: injection volume, 10 μL; column, Atlantis HILIC silica column, 4.6 × 150 mm, 3 μm (Waters Corp.); flow rate, 1.4 mL/min; detector was used at 254 nm. Standard curves were obtained using the standard (Sigma) for each compound and then used for calculation of betaine and L-carnitine contents.

Statistical analysis

Statistical analysis was performed using multifactorial analysis of variance (ANOVA) to estimate the effect of the breed and sex on quality traits and bioactive compound content of duck meat, and the significant differences between the mean values were identified with Tukey's multiple range test using SAS software at a confidence level of $p<0.05$ (SAS 9.3, SAS Institute Inc., USA).

Results and Discussion

Carcass and breast weights

Table 1 shows the effects of breed and sex on carcass and breast weights of ducks; KND had a significantly higher carcass weight than CD ($p<0.05$) whereas no such difference was found between male and female ducks (Table 1). As KND was known for their inferior growth rate compared with commercial breeds, NIAS made considerable efforts to improve the growth rate and developed KND in two main types; small-type and large-type (Heo *et al*., 2013; Kim *et al*., 2012a). Heo *et al*. (2013) evaluated the growth of large-type KND with increasing age and reported that KND reached a carcass weight of 1,801±50.6 g and a breast weight of 469.2±15.8 g at 6 wk of their age which is similar to the results of the present study.

Table 1. Carcass and breast weights (g) of Korean native ducks (KND) and commercial ducks (CD)

Item	Breed		Sex		SEM[1]
	KND	CD	Male	Female	
Carcass weight	1898[a]	1745[b]	1866	1777	34.2
Breast weight	352	325	330	348	11.5
Corr[2]	0.32	0.11	0.58	0.81	-

[1]Standard error of the means (n=12).
[2]Corr = correlation coefficient between carcass and breast weight at $p<0.05$.
[a,b]Means within the same row with different letters within the same effect differ significantly ($p<0.05$).

Table 2. Meat quality traits of the breast meat from male and female Korean native ducks (KND) and commercial ducks (CD)

Quality traits	Breed		Sex		SEM[1]
	KND	CD	Male	Female	
pH	5.93	5.90	5.91	5.92	0.015
Cooking loss (%)	32.65[b]	37.04[a]	35.74[a]	33.95[b]	0.365
Shear force (kg)	2.59	2.72	2.60	2.71	0.063
CIE L*	42.86[b]	45.02[a]	44.91[a]	42.97[b]	0.492
CIE a*	21.26	20.43	20.86	20.84	0.355
CIE b*	7.28	6.81	7.47[a]	6.62[b]	0.244

[1]Standard error of the means (n=12).
[a,b]Means within the same row with different letters within the same effect differ significantly ($p<0.05$).

Meat quality traits

The breed and sex of duck did not affect the pH value of breast meat in the present study (Table 2), and it is in agreement with the findings of Muhlisin *et al*. (2013). Furthermore, the pH value of breast meat observed in the present study was closer to that of Pekin ducks (Kim *et al*., 2012b). In contrast, several other researchers have reported much higher pH values for duck meat from A44 and A55 strains (6.0 and 6.4, respectively). However, the breed × sex interaction ($p=0.04$) was found to be significant regarding the pH value of duck meat.

The pH value is one of the most important factors affecting meat quality traits because it has a direct effect on denaturation of meat proteins, influencing tenderness and water holding capacity and meat color (Hamoen *et al*., 2013). In our findings, pH value did not seem to have a positive effect on water holding capacity as a significant difference was found in cooking loss values between KND (32.65%) and CD (37.04%). Additionally, the sex and breed × sex interaction had significant effects on cooking loss values, in order of significance. Male ducks showed higher cooking loss values compared with female birds ($p<0.05$; Table 2). The shear force values of the duck breast meat were comparable between the breeds and sexes (Table 2). The shear force values of duck meat tested in this study was similar to that observed by Muhlisin *et al*. (2013) for imported CD (2.73). However, several previous studies have shown much higher shear force values for duck meat from Chungdongori (3.76; Ali *et al*., 2008) and Pekin ducks (4.18; Kim *et al*., 2012b). The difference in shear force values among these studies might be attributable to the difference in breed and slaughter age (Muhlisin *et al*., 2013).

CIE color values of KND meat were reported as 36.9 ±0.97, 21.6±0.94, and 8.78±0.64 for L*-, a*-, and b*-values, respectively (Kim *et al*., 2010b). Our results showed a higher L*-value (42.97-45.02), a similar a*-value (20.43-21.26), and a lower b*-value (6.62-7.47) compared to those of Kim *et al.* (2010b). However, Chae *et al*. (2005) reported meat color values of duck meat to be 39.80-46.51, 16.67-17.92, and 4.37-7.27 for L*-, a*-, and b*-values, respectively. Both breed and sex showed a significant effect on L*-value of duck breast meat (Table 2). In this regards, L*-value was higher ($p<0.05$) in CD and male duck meats compared to their counterparts. In addition, b*-value was higher in the meat from male ducks compared to that from female ducks, but comparable between the breeds. Joo *et al*. (2013) explained the relationship between L*-value and water holding capacity of meat. With lowered water holding capacity, a higher loss of myoglobin and a greater reflection of light at the meat surface result in a higher L*-value. The b*-value can be related to L*-value since intracellular fat content affects the increase in b*-value and has a positive relationship with L*-value (Sarries and Beriain, 2006). This explanation agrees with our findings regarding the significant difference observed in the L*-value between breeds and sexes. However, since there was no significant difference

in the a*-value, which is known to be affected by the myoglobin content (Quevedo *et al*., 2013), the reflection of light at the meat surface and b*-value of meat must have contributed a greater proportion towards the higher L*-values observed in the current study.

Bioactive compounds

No scientific publications that compare the bioactive compounds of different breeds of ducks are available. Only a few studies have reported the presence of these endogenous compounds in meat from other species. Hence, these studies were considered in the following section to put our current findings into context. The contents of creatine, anserine, and L-carnitine in duck breast meat were affected by breed and sex (Table 3).

Creatine performs an important role in the energy metabolism of skeletal muscle (Wyss and Kaddurah-Daouk, 2000). Creatine is absorbed into body from meat and meat products after consumption, and it increases muscle power and performance (Schmid, 2009). A strong effect of the breed and sex on the creatine content of duck breast meat was observed in the present study; KND and female birds showed significantly higher creatine contents than their counterparts (Table 3). A previous study showed similar findings regarding the creatine content of Korean native chickens (KNC); female KNC had significantly higher creatine content than male KNC (Jayasena *et al*., 2015). In contrast, Jung *et al*. (2013) revealed that sex did not influence the creatine content of KNC meat, but influenced the line of KNC ($p<0.0001$).

Carnosine and anserine are dipeptides composed of β-alanine and L-histidine and anserine is derived from carnosine (Hipkiss, 1998; Stenesh and Winnick, 1960). These compounds have pH buffering, antioxidative, and antiaging roles. In addition, meat and meat products are the main dietary source of carnosine and anserine for humans (Schmid, 2009). Comparable carnosine contents were found ($p>0.05$) between the two breeds and between male and female birds in the current study (Table 3). In contrast, Jayasena *et al*. (2014b) reported that the carnosine content of KNC meat was significantly higher than that of commercial broiler (CB) meat ($p<0.05$). Marlin *et al*. (1989) and Mateescu *et al*. (2012) demonstrated that carnosine content was not related to sex of the animal. However, Jung *et al*. (2013) demonstrated a sex effect on the carnosine content of KNC meat; female birds had significantly higher carnosine contents than did male birds.

The present study showed that the breed, sex, and breed × sex interaction significantly affected the anserine content of duck breast meat, in order of significance (data not shown). In this regards, KND and female ducks showed higher anserine contents in the breast meat (49.18 and 46.64 mg/100 g, respectively) compared with CD and male ducks (36.72 and 39.27 mg/100 g, respectively). This is in well agreement with the results of Jayasena *et al*. (2014b) who observed that the anserine content of KNC meat was significantly higher than that of CB meat ($p<0.05$). However, Jung *et al*. (2013) found that the anserine content of KNC meat was also not affected by the bird sex. Peñafiel *et al*. (2004) explained that carnosine content has a positive correlation with testosterone. In addition, duck meat contained more anserine than carnosine, irrespective of the breed and sex, which is in agreement with previous findings that anserine was the principal histidine dipeptide in poultry meat (Abe and Okuma, 1995; Jayasena *et al*., 2014a). The anserine contents of meat are governed by muscle type, species, breed, gender, age, and breeding (Abe and Okuma, 1995; Chan and Decker, 1994; Jayasena *et al*., 2014a). Hence, the higher anserine content of KND meat compared to that of CD meat may be attributed to breed effect.

Betaine acts as an osmolyte to preserve osmotic equilibrium and also interacts with fat metabolism resulting in fat reduction (de Zwart *et al*., 2003; Fernández *et al*., 1998). According to the findings of the current study, the betaine content of duck breast meat was similar ($p>0.05$)

Table 3. Bioactive compound content of the breast meat (mg/100 g) from male and female Korean native ducks (KND) and commercial ducks (CD)

Compound	Breed		Sex		SEM[1]
	KND	CD	Male	Female	
Creatine	128.99[a]	121.85[b]	119.59[b]	131.25[a]	1.275
Carnosine	14.36	16.49	15.90	14.95	1.114
Anserine	49.18[a]	36.72[b]	39.27[b]	46.64[a]	2.051
Betaine	4.06	4.04	3.90	4.21	0.201
L-carnitine	8.33[a]	6.76[b]	6.83[b]	8.26[a]	0.272

[1]Standard error of the means (n=12).

[a,b]Means within the same row with different letters within the same effect differ significantly ($p<0.05$).

between KND (4.06 mg/100 g) and CD (4.04 mg/100 g) and between male ducks (3.90 mg/100 g) and females (4.21 mg/100 g; Table 3). KNC had a betaine content of 3.55-5.05 mg/100 g (Jayasena *et al*., 2014a). In contrast, Jayasena *et al*. (2014b) revealed that the betaine content of KNC meat was significantly lower than that of CB meat ($p<0.05$). L-carnitine combines with long chained fatty acids forming L-carnitine esters and fat combustion takes place though β-oxidation in mitochondria (Schmid, 2009). According to our results, L-carnitine content of duck breast meat was influenced both by the breed and sex, in order of significance (data not shown). The L-carnitine contents of KND and CD were 8.33 mg/100 g and 6.76 mg/100 g whereas those of male and female ducks were 6.83 mg/100 g and 8.26 mg/100 g, respectively (Table 3). Similarly, L-carnitine content of KNC meat was significantly higher than that of CB meat (Jayasena *et al*., 2014b).

In general, KNC had higher bioactive compound contents (Jayasena *et al*., 2014a; Jung *et al*., 2013), except betaine and L-carnitine, compared to KND. This confirms that bioactive compound content of meat is dependent on the animal species. Table 4 shows that the carnosine and anserine contents were positively related (0.04 and 0.81, respectively) to the breast weight of KND and negatively related (-0.40 and -0.18, respectively) to that of CD.

In addition, the betaine, L-carnitine, and creatine contents were related to the breast weight of KND compared with that of CD (Table 4).

Conclusion

KND had a higher carcass weight and a lower cooking loss value compared to CD. Furthermore, the KND contained higher levels of creatine, anserine, and L-carnitine than CD. The content of same compounds was higher in female ducks than in males. The findings of the present study are useful to disseminate the information regarding the availability and amounts of bioactive compounds in duck meat, particularly in KND meat. However, further studies on endogenous compounds in duck meat from genetically-proven KND such as Woorimatori^{TM} and CD should be investigated.

Table 4. Pearson's correlation coefficient of bioactive compounds and breast weight from male and female Korean native ducks (KND) and commercial ducks (CD)

Compound	Breed		Sex	
	KND	CD	Male	Female
Creatine	0.71	0.38	0.87	0.63
Carnosine	0.04	-0.40	-0.37	0.20
Anserine	0.81	-0.18	0.62	0.63
Betaine	0.59	0.56	0.37	0.66
L-carnitine	0.68	0.12	0.38	0.70

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