

The Growth Performance, Carcass Characteristics, and Meat Quality of Egg-Type Male Growing Chicken and White-Mini Broiler in Comparison with Commercial Broiler (Ross 308)

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Abstract

The present study was conducted to compare the growth performance, carcass characteristics, and meat quality of the egg-type male growing chicken (EM), white-mini broiler (WB), and commercial broiler (Ross 308, CB). A total of 360 1-d-old chicks were reared together using a completely randomized design with 4 replicates for each group under the identical feeding and rearing conditions. The ADG and gain:feed were the highest in CB, intermediate in WB, and the lowest in EM ($p < 0.05$), and the live and carcass weights of CB and EM were significantly higher than those of WB ($p < 0.05$). The pH of breast meat from WB and CB was significantly higher ($p < 0.05$) than that from EM with a similar body weight. The EM had the lowest moisture ($p < 0.05$) and the highest protein content ($p < 0.05$), whereas the fat and ash contents were not different among groups. The myristic acid (C14:0), palmitoleic acid (C16:1 ω 7), and oleic acid (C18:1 ω 9) levels were significantly higher in breast meat from CB ($p < 0.05$). The monounsaturated fatty acid (MUFA) content showed the highest ($p < 0.05$) levels in CB. In contrast, the polyunsaturated fatty acid (PUFA) contents of breast meat, including linoleic acid (C18:2 ω 6) and arachidonic acid (C20:4 ω 6), were higher ($p < 0.05$) in EM and WB than in CB. In conclusion, the EM and WB had less growth performances in comparison with CB, but they each had some unique features (taste, flavor, and physiological characteristics) when raised under the identical rearing and feeding conditions.

Keywords: egg-type male growing chicken, white-mini broiler, commercial broiler, meat quality

Introduction

The demand for chicken meat products in foreign and domestic markets has risen because of the accelerated increase in global population and the consumer perception of health benefits associated with chicken meat (López *et al.*, 2011). Chicken meat consumption is expected to increase by a further 34% by the year 2018 with a concomitant fall in price of 15%. This means that chicken will continue to be the cheapest commercially produced meat (Jung *et al.*, 2011). However, only a few fast-growing broiler strains produced by commercial breeding companies are used to produce chicken meat (Jaturasitha

et al., 2008) because they can be sent to the market within 5 to 6 wk, providing greater economic benefits (Choe *et al.*, 2009). As the economy and globalization of the food industry continues to grow, the consumer interest in various chicken meats is being steadily increased every year. The chicken meat industry in East Asia and Europe has produced various chicken meats that retail at 2 to 5 times the price of commercial broilers (CB) (Rikimaru and Takahashi, 2010; Yang and Jiang, 2005).

The various chicken meats available in Korea are characterized by outstanding flavor from chickens with rapid growth rates (Kang *et al.*, 2010; Park *et al.*, 2010a, b), and are often roasted or braised with vegetables, or used in soups. Two of the most well-known cuisines are Samgyetang and Baeksuk that are traditionally prepared using white-mini broiler (WB) and egg-type male growing chicken (EM), braised in a soup with various oriental medicinal plants, and eaten during the summer time to over-

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come heat (Nam *et al.*, 2010). The WB, a local mixed breed produced by crossbreeding between meat-type male breeder and egg-type hens, is a popular brand in Korea. Approximately 3.34 billion egg-type male chicks hatch globally each year, but their subsequent disposal is a common procedure in the egg industry. Euthanasia of these egg-type male chicks comes at a significant cost to the egg industry considering the expenses of electrical energy lost during incubation and the environmental problems associated with residue discharge from hatcheries (Bertechini *et al.*, 2014). Because the egg industry has been under pressure from animal protection groups, sustainable solutions that utilize these males are needed. Furthermore, the use of these animals as a source of animal protein for human consumption should be considered (Bertechini *et al.*, 2014).

Meat from egg-type male growing chicken is tougher than that from CB, but the taste, flavor, juiciness, and tenderness are almost similar to that of the quality chickens such as Three Yellow of China, *Label Rouge* of France, and *QualiteWallon* of Belgium (Huque *et al.*, 2004). It is important to elucidate the physicochemical factors that influence the taste and flavor of the chicken meat, and the unique taste and flavor of EM and WB in comparison to CB has yet to be scientifically evaluated (Jayasena *et al.*, 2013). The poultry markets used to produce various chicken meats represent a growing opportunity, but little is known about the growth performance and meat quality of the EM and WB used in Korea. Therefore, the objective of the current study was to compare growth performance, carcass characteristics, and meat quality of EM, WB, and CB.

Materials and Methods

Animals, diets, and management

A total of 360 egg-type male growing chicken (EM, Hy-Line brown males), white-mini broiler (WB), and commercial broiler (CB, Ross 308) at 1 d of age were weighed and completely randomly assigned into 3 treatments. Each treatment was comprised of 4 replicates. Thirty chicks per each pen were raised for 51 d (EM), 28 d (WB), and 21 d (CB), respectively to obtain similar slaughter weights. The chicks were fed the same commercial diet (21% CP, 3,050 kcal of TME/kg) from 1 d until the end of the experimental period. Nutrient and energy concentrations of experimental diets met, or exceeded, the minimum requirements of the National Research Council (1994). The formula and chemical compositions of experimental diets are

shown in Table 1. Feed was provided *ad libitum* and the birds had free access to water. The BW and feed consumption were measured weekly in all pens. Average daily gain, ADFI, and gain:feed were calculated for each pen. Animal facilities and husbandry were similar to the conditions described by An *et al.* (1995). Lighting was kept at 23/1 light/dark cycle throughout the experimental period. Initially, chicks were maintained at 33°C; and the temperature was gradually decreased by 4°C weekly until it reached 22°C at the end of the experiment. All animal care and experimental procedures conformed to the ethical regulations and guidelines of Konkuk University in Korea.

Sampling and measurements of physiological characteristics

Following 12 h of feed deprivation at the end of the experimental period, 8 chicks (2 chicks of average BW were selected from each pen) from each treatment were euthanized. After bleeding, the chicks were scalded in

Table 1. Feed formula and chemical composition of the basal diet, as-fed basis

Items	
Ingredients	%
Yellow corn	54.38
Soybean meal, 47% CP	30.51
Corn gluten meal, 60% CP	3.00
Wheat bran	5.46
Tallow	3.00
Vitamin and trace mineral premix ¹	0.22
L-Lysine-HCl, 78%	0.01
DL-Methionine, 98.5%	0.18
L-Threonine, 98%	0.02
Dicalcium phosphate	1.87
Limestone	0.94
Choline-Cl, 50%	0.09
Salt	0.32
Calculated composition	
TME _n , kcal/kg	3,050
CP, %	21.0
Ca, %	1.00
Available P, %	0.45
Lysine, %	1.10
Methionine + Cystine, %	0.90

¹Vitamin and trace mineral premix provided the following nutrients per kg of diet: vitamin A, 40,000 IU; vitamin D₃, 8,000 IU; vitamin E, 10 IU; vitamin K₃, 4.0 mg; vitamin B₁, 4.0 mg; vitamin B₂, 12.0 mg; vitamin B₆, 6.0 mg; vitamin B₁₂, 0.02 mg; niacin, 60.0 mg; pantothenic acid, 20 mg; folic acid, 2.0 mg; biotin, 0.02 mg; Fe, 30.0 mg (as FeSO₄H₂O); Zn, 25.0 mg (as ZnSO₄H₂O); Mn, 20.0 mg (as MnSO₄H₂O); Cu, 5.0 mg (as CuSO₄H₂O); Se, 0.1 mg (as Na₂SeO₃).

boiling water (60°C for 45 s before defeathering and eviscerating) and then the feathers were removed. The carcass weight was calculated by removing the feathers, blood, head, feet, and all organs except from the lungs and kidneys. The carcass yield was expressed as a percentage of live weight.

The pH values of breast meat from each chick were measured using a pH meter (Model 340, Mettler-Toledo, Switzerland). Approximately 1 g of meat was cut into small pieces and homogenized in 9 mL of distilled water for 60 s in an Ultra-Turrax (Model No. T-25, Janke and Kunkel, Germany). The mean values of 3 measurements from each sample were used. The breast meat color was measured on the surface of samples using a Chromameter (CR210, Minolta, Japan), which was standardized using a white tile. Color for each sample was expressed in terms of Commission international de l'Eclairage values for lightness (L^*), redness (a^*), and yellowness (b^*), and was obtained using the average value of 3 measurements taken from different locations on the meat surface. After 24 h postmortem, 1.5 cm breast muscles weighing approximately 30 g were placed in a polyethylene bag. The package was heated in a water bath at 80°C for 30 min and cooled at room temperature for 30 min. Cooking loss percentage was determined by the steak weight taken before and after cooking. Furthermore, 6 representative 1.27 cm diameter cores were removed from each steak parallel to the muscle fiber after cooling. Shear force values were determined with a Warner-Bratzler shear attachment on an Instron universal testing machine (Instron Corporation, USA) using the following operating parameters: load cell, 50 kg, cross-head speed, and 200 mm/min. Each core sample was sheared once across the center of the core perpendicular to the muscle fiber. The shear-force value was the mean of the maximum forces required to shear each set of core samples. Water holding capacity (WHC) was measured using a modification of the method used by Grau and Hamm (1953). Briefly, a 300 mg sample of breast meat was placed in a filter-press device and compressed for 3 min. Water holding capacity was calculated from samples in duplicate as a ratio of the meat film area to the total area.

Proximate composition

The proximate composition of the breast meat from the left side was determined using the methods of the AOAC (2007). Briefly, the moisture content was measured by drying the samples (2 g) at 105°C for 2 h. The crude protein content was measured by the Kjeldahl method (BU-

CHI Kjeldahl Distillation Unit B-324, Germany). The chloroform/methanol (1:2 v/v) extraction method described by Folch *et al.* (1957) was used to determine the total lipid content of a 2 g homogenized meat sample. The crude ash content was measured by heating the sample (2 g) in a furnace at 550°C for 3 h.

Fatty acid composition

Lipids were extracted from breast meat using the methods described by Folch *et al.* (1957). Briefly, 5 g of sample was homogenized with 25 mL of chloroform:methanol (2:1, v/v) at 13,500 rpm using a homogenizer (Ultra Turax T25 basic, Ika Werke GmbH & Co., Germany). KCl (0.88%) was added to the homogenates, which were then centrifuged at 3,000 rpm for 10 min. The supernatant was evaporated at 38°C on an N₂ gas blow concentrator (MG 2200, Eyela Co., Japan). The methylation was performed according to AOAC (2007). The fatty acid composition was analyzed in an Agilent 6890 N (Agilent Technologies, USA) equipped with an automatic sampler Agilent 7683 (Agilent Technologies, USA) using an HP-Innowax (30 m length × 0.32 mm i.d. × 0.25 μm film thickness; Agilent Technologies, USA). One microliter of sample was injected (split 1:10; 260°C), and the flow rate was 1.0 mL/min by using helium. The oven temperature was set at 150°C for 1 min, 150-200°C at 15°C/min, 200-25°C at 3°C/min, and 250°C for 5 min. The detector (FID) was set at 280°C.

Statistical analysis

All data were analyzed by ANOVA as a completely random design using the GLM procedure of SAS (SAS, 1986). The model included genotype as a fixed variable, and period and sex within replication as random variables. If the F-test for treatment effect was significant, differences between treatment means were determined using the Duncan's multiple range test (Duncan, 1955). The experimental unit was a pen, and significance was determined at α of 0.05.

Results and Discussion

Growth performance

Growth performance of EM, WB, and CB increased under identical diet and feeding conditions are presented in Table 2. The ADG and gain:feed were the highest in CB, intermediate in WB, and the lowest in EM ($p < 0.05$), consistent with previous reports (Khawaja *et al.*, 2012; Lichovnikova *et al.*, 2009; Lonergan *et al.*, 2003). Huque *et al.* (2004) investigated the effect of age on growth per-

Table 2. Growth performance of egg-type male growing chickens, white-mini broilers and commercial broilers¹

Items ²	Egg-type male growing chicken (51d) ³	White-mini broiler (28d)	Commercial Broiler (21d)	SEM	<i>p</i> -value
Initial BW, g/bird	41.60 ^a	41.57 ^a	41.50 ^b	0.01	0.005
Final BW, g/bird	750.67 ^b	686.11 ^b	999.62 ^a	36.76	0.002
ADFI, g/day	50.12	42.59	49.30	3.62	0.340
ADG, g/day	13.90 ^c	23.02 ^b	41.66 ^a	1.27	<0.001
Gain:feed	0.28 ^c	0.56 ^b	0.85 ^a	0.05	<0.001

^{a-c}Least square of means within a row without a common superscript letter differ ($p < 0.05$).

¹Each least squares mean represents 4 pens with 30 birds per pen.

²BW, Body Weight; ADFI, Average Daily Feed Intake; ADG, Average Daily Gain.

³The number of days in the parenthesis represents each experimental period.

Table 3. The carcass characteristics of egg-type male growing chickens, white-mini broilers and commercial broilers¹

Items	Egg-type male growing chicken (51d) ²	White-mini broiler (28d)	Commercial Broiler (21d)	SEM	<i>p</i> -value
Live weight, g	830.00 ^a	662.50 ^b	836.25 ^a	7.99	<0.001
Carcass weight, g	535.13 ^a	431.70 ^b	542.59 ^a	8.49	<0.001
Carcass yield, % ³	64.47	65.17	64.85	0.66	0.760
% for carcass ⁴					
Breasts	8.11 ^c	9.78 ^b	14.01 ^a	0.42	<0.001
Legs	18.62 ^a	18.55 ^a	16.99 ^b	0.25	<0.001
Wings	7.25 ^a	6.82 ^a	5.44 ^b	0.20	<0.001

^{a,b}Least square of means within a row without a common superscript letter differ ($p < 0.05$).

¹Each least squares mean represents 4 pens with 2 birds sampled per pen.

²The number of days in the parenthesis represents each experimental period.

³The carcass yield is based on the live weight of chickens.

⁴The meat yield and liver index is based on the carcass weight of chickens.

formance and dressing percentage in 4 strains of EM reared under identical conditions. They found that ADG, ADFI, and gain:feed in Hy-Line brown male chicks were 12.87 g, 45.75 g, and 0.28, respectively. In the current study, ADG and ADFI of EM were slightly higher than those reported by Huque *et al.* (2004); however, the value of gain:feed was consistent with their report. Many quality chickens are available in Europe, and researchers have reported that the growth performance of CB is more efficient than that in these quality chickens. Because much of the change has been brought about by commercial breeding organizations, the growth rate of commercial broilers has changed tremendously over the past 45 years (Havenstein *et al.*, 2003). In addition, WB is derived from crossbreeding Ross 308 and Hy-Line brown layer, and further crossbreeding could lead to the production of birds with better growth rates, improved gain:feed efficiency, and reproductive traits without sacrificing adaption to the local environment (An *et al.*, 2009). This would also reduce production costs (Adebambo *et al.*, 2011). Therefore, it is likely that the performance of WB has been greatly improved by crossbreeding.

Carcass characteristics

Carcass characteristics of EM, WB, and CB are presented in Table 3. The live weights and carcass weights of CB and EM were significantly higher than those of WB ($p < 0.05$), and the breast yield was significantly higher in CB than in EM and WB ($p < 0.05$). Carcass and breast yield are affected by a number of factors, including genetic, feed, slaughtering conditions, live weight, sex, and age (Brickett *et al.*, 2007; Havenstein *et al.*, 2003; Young *et al.*, 2001). Lewis *et al.* (1997) compared the quality of weight-matched carcasses from slow- and fast-growing chickens and did not find any significant differences in the breast, leg, or total meat production. On the other hand, Gerkene *et al.* (2003) found that the proportion of the edible part and the leg yield tended to be higher in EM than CB. Furthermore, Fanatico *et al.* (2005a) observed a significant effect of genotype on the breast and leg yield. Using slow-growing chickens, they found that the breast yield was lower, whereas the leg yield was higher in comparison with CB. Because the 3 chicken breeds used in this study were reared under identical conditions, the differences found in our study can be attributed to the difference in chicken breeds.

Meat quality

The cooking loss, WHC, pH, and color of breast meat from EM, WB, and CB are presented in Table 4. The pH of breast meat from WB and CB was significantly higher ($p<0.05$) than that from EM with similar body weight. No significant differences were observed in shear-force, cooking loss, and WHC among groups. The pH value of meat has been associated with attributes such as tenderness, WHC, cooking loss, juiciness, and shelf life (Allen *et al.*, 1998). Husak *et al.* (2008) reported that higher pH in meat is more effective for retaining a desirable color and moisture absorption properties. The breast meat from EM showed significantly higher ($p<0.05$) lightness (CIE L*) and redness (CIE a*) than that from WB and CB, although there were no differences in yellowness (CIE b*). Consumers first evaluate meat products by visual appraisal; therefore, there is a lot of interest in the factors that influence the color of breast meat. Qiao *et al.* (2002) demonstrated a strong negative correlation between CB breast pH and lightness (L*) values, and a positive correlation between pH and redness (a*) values. In addition, Allen *et al.* (1997) found that low pH was associated with light-colored breast meat, which is consistent with the present results.

The chemical and fatty acid compositions of EM, WB, and CB are presented in Tables 5 and 6. The moisture con-

tent of EM was the lowest ($p<0.05$), and the protein content was the highest ($p<0.05$), whereas the fat and ash contents were not different among groups. The moisture content in the breast meat from slow-growing chickens was higher than that from CB (Holcman *et al.*, 2003). Further, the breast meat from CB contained higher fat and lower protein content than that from slow-growing chickens (Lonergan *et al.*, 2003). The moisture and protein content have been associated with numerous factors. Fanatico *et al.* (2005b) showed that there was higher moisture content in fast-growing chickens, although they compared birds of the same weight but at different ages. Furthermore, Lichovniková *et al.* (2009) found that age (maturity) of the animals significantly affected the moisture content of breast meat. The mystiric acid (C14:0), palmitoleic acid (C16:1 ω 7), vaccenic acid (C18:1 ω 7), and oleic acid (C18:1 ω 9) contents were significantly higher in breast meat from CB ($p<0.05$). The mono-unsaturated fatty acid (MUFA) content, which in chickens is related to its endogenous synthesis or to its absorption in the gut from the diet (Dal Bosco *et al.*, 2012), showed the highest ($p<0.05$) levels in CB; these MUFA concentrations were mainly represented by oleic and palmitoleic acid. Because 3 breeds of chicken used in this study were raised under the identical rearing and feeding conditions, and thus the differences of MUFA contents are assumed to be due to

Table 4. The physiological characteristics of egg-type male growing chickens, white-mini broilers and commercial broilers¹

Items ²	Egg-type male growing chicken (51d) ³	White-mini broiler (28d)	Commercial Broiler (21d)	SEM	p-value
Shear force, kgf	2.41	2.64	2.80	0.12	0.101
Cooking loss, %	23.98	23.13	23.95	0.87	0.738
WHC, %	57.41	54.38	57.79	1.78	0.352
pH	6.68 ^b	7.00 ^a	6.97 ^a	0.08	0.024
L*	59.51 ^a	53.52 ^b	53.95 ^b	1.00	<0.001
CIE a*	1.22 ^b	2.68 ^a	3.62 ^a	0.32	<0.001
b*	6.96	7.34	7.55	0.52	0.719

^{a,b}Least square of means within a row without a common superscript letter differ ($p<0.05$).

¹Each least squares mean represents 4 pens with 2 birds sampled per pen.

²WHC, Water holding capacity; CIE, Commission international de l'Eclairage; L*, lightness; a*, redness; b*, yellowness.

³The number of days in the parenthesis represents each experimental period.

Table 5. The proximate composition of egg-type male growing chickens, white-mini broilers and commercial broilers¹

Items	Egg-type male growing chicken (51d) ²	White-mini broiler (28d)	Commercial Broiler (21d)	SEM	p-value
Moisture, %	72.77 ^b	76.04 ^a	75.40 ^a	0.46	<0.001
Protein, %	25.19 ^a	22.02 ^b	22.57 ^b	0.36	<0.001
Fat, %	1.77	1.67	1.74	0.09	0.726
Ash, %	0.27	0.28	0.29	0.01	0.155

^{a,b}Least square of means within a row without a common superscript letter differ ($p<0.05$).

¹Each least squares mean represents 4 pens with 2 birds sampled per pen.

²The number of days in the parenthesis represents each experimental period.

Table 6. The fatty acid composition of egg-type male growing chickens, white-mini broilers and commercial broilers¹

Items	Egg-type male growing chicken (51d) ³	White-mini broiler (28d)	Commercial Broiler (21d)	SEM	p-value
Mystiric acid (C14:0) ²	1.03 ^b	1.16 ^b	1.80 ^a	0.09	<0.001
Palmitic acid (C16:0)	22.27	22.74	22.18	0.60	0.784
Stearic acid (C18:0)	11.79	11.17	9.67	0.95	0.295
SFA	35.09	35.07	33.64	1.21	0.634
Palmitoleic acid (C16:1 ω7)	3.06 ^b	2.97 ^b	4.20 ^a	0.30	0.020
Oleic acid (C18:1 ω9)	27.25 ^b	27.35 ^b	33.85 ^a	0.92	<0.001
Vaccenic acid (C18:1 ω7)	0.11 ^c	0.18 ^b	0.26 ^a	0.02	<0.001
Cis-eicosonic acid (C20:1 ω9)	0.38 ^b	0.59 ^a	0.57 ^a	0.03	0.001
MUFA	30.81 ^b	31.08 ^b	38.88 ^a	1.14	<0.001
Linoleic acid (C18:2 ω6)	24.69 ^a	24.07 ^a	19.88 ^b	0.70	<0.001
γ-Linolenic acid (C18:3 ω6)	0.23	0.18	0.20	0.02	0.249
Arachidonic acid (C20:4 ω6)	6.82 ^a	5.63 ^a	3.64 ^b	0.61	0.007
Docosatetraenoic acid (C22:4 ω6)	0.85	0.97	0.82	0.10	0.523
n-6	32.59 ^a	30.85 ^a	24.54 ^b	1.01	<0.001
α-Linolenic acid (C18:3 ω3)	0.72 ^{ab}	0.66 ^b	0.92 ^a	0.07	0.041
Eicosepentaenoic acid (C20:5 ω3)	0.18 ^b	0.37 ^a	0.24 ^b	0.03	0.005
Docosahexaenoic acid (C22:6 ω3)	0.61	1.97	1.77	0.38	0.051
n-3	1.51 ^b	3.00 ^a	2.93 ^a	0.36	0.018
PUFA	34.11 ^a	33.84 ^a	27.48 ^b	1.07	0.001

^{a,b}Least square of means within a row without a common superscript letter differ ($p < 0.05$).

¹Each least squares mean represents 4 pens with 2 birds sampled per pen.

²Fatty acids were denoted by the number of carbons: number of double, followed by the position of the first double bond. SFA, saturated fatty acid; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid.

⁴The number of days in the parenthesis represents each experimental period.

genetic influence. In contrast, the polyunsaturated fatty acid (PUFA) content of breast meat, including essential fatty acids such as linoleic acid (C18:2 ω6) and arachidonic acid (C20:4 ω6), were higher ($p < 0.05$) in EM and WB than in CB. Kiyohara *et al.* (2010) demonstrated that total taste intensity and aftertaste of both chicken soup and meat were significantly higher when birds were fed an arachidonic acid-enriched diet. The authors suggest that the palatability of chicken meat can be improved by dietary arachidonic acid supplementation (Kiyohara *et al.*, 2010). Dal Bosco *et al.* (2012) observed differences in the total SFA content, such that the higher value was observed in layer and the lower value in CB. Similar to the results of the present study, CB meat was observed to have higher ($p < 0.05$) palmitoleic and oleic acid contents (Jayasena *et al.*, 2013; Jeon *et al.*, 2010; Jung *et al.*, 2011). The difference in fatty acid composition is possibly due to dietary differences (Cherian *et al.*, 2002) as well as differences in feeding behavior between breeds (Wattanachant *et al.*, 2004). Because all of the chickens in this study were provided with the same diet, the differences observed in the fatty acid profiles are likely due to the genotype.

In conclusion, the results of our study indicate that growth performance, carcass characteristics, and meat

quality differ between chicken breeds. Compared with CB and EM, WB showed lower growth performance. In addition, unique features in meat quality were observed in each breed when reared under the identical conditions.

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