International Journal of Agricultural Technology 2022Vol. 18(2):567-578
Available online http://www.ijat-aatsea.com
ISSN 2630-0192 (Online)

Effect of strain and gender on production performance, carcass characteristics and meat quality of broiler chickens

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Kamporn, K., Deeden, B., Klompanya, A., Setakul, S., Chaosap, C. and Sittigaipong, R. (2022). Effect of strain and gender on production performance, carcass characteristics and meat quality of broiler chickens. International Journal of Agricultural Technology 18(2):567-578.

Abstract The effects of strain and gender on production performance, carcass characteristics, and meat quality of broiler chickens were examined. There were no significant interactions between broiler strain and gender (P>0.05). Arbor Acres showed significantly higher body weight (BW) and average daily gain (ADG), while feed intake (FI) and feed conversion ratio (FCR) were significantly lower than Ross308 and Cobb500, especially in the fifth and sixth weeks of age. Arbor Acres also showed the highest slaughter weight (P<0.05). However, carcass composition was not significantly different between strains. There were no significant differences between the strains in muscle pH, drip loss and cooking loss. However, Cobb500 had a lower shear force value than the others (P<0.05). As for the gender-specific effect, BW and ADG of male broilers were higher than those of females from the second to the sixth week of age (P<0.01). At the second week of age, female broilers had higher FI, while male broilers had higher FI from the third to the sixth week of age (P<0.01). Male broilers had lower FCR than females from the fourth to the sixth week of age (P<0.01). Male broilers had higher slaughter weight, carcass weight and carcass composition weight (P<0.01) except for abdominal fat (P>0.05). Percent carcass composition did not differ among broiler strains except for percent tenderloin and percent abdominal fat, which were higher in females than males (P<0.01). Broiler strains had no effect on meat quality except that Cobb500 had lower shear force (P<0.05). The pH_3, pH_{24} and yellowness color values had differed between genders, which male muscle had higher pH_3 (P<0.05), pH_{24} (P<0.01) than female but female muscle had higher yellowness value than male (P<0.05). Interaction effect between breed and gender was found in lightness (P<0.01) and redness colors (P<0.05).

Keywords: Broiler, Performance, Carcass composition, Meat quality

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Introduction

The most important livestock industry in Thailand is poultry production, predominately broilers. It plays a major role in supplying chicken meat for domestic consumption and export. In 2019, there were 32,631 broiler chicken farms with a total number of 1,684.26 million birds or 2.49 million tons of chicken meat per year, of which 900,000 tons were exported (DLD Data and Information Center, 2020). The trend of exporting chicken meat will continue as producers have improved farm productivity, strict animal disease and food safety controls are implemented, and the development of final products acceptable to both domestic and international consumers has advanced.

The most important economic production performance characteristics of broiler chickens are body weight (BW), feed intake (FI) and feed conversion ratio (FCR). Nowadays, the broiler industry is focusing on raising birds based on carcass characteristics (Petracci *et al.,* 2015) as consumers have shifted from the consumption of whole chicken to the consumption of cuts (Abdullah *et al.,* 2010). These changes have driven the broiler industry to put an emphasis on the importance of carcass percentage and meat quality such as breast meat, wing, thigh, drumstick, meat pH and sheer force of meat, with strain and gender influencing the expression of these traits (Lopez *et al*., 2011).

There are numerous strains of broiler worldwide. Which strains are used by farmers depends on which strain is available in that particular locality or country. Arbor Acres, Ross, Hubbard, Anek and Cobb are commonly used for commercial production in Thailand. Several reports indicate that genotype affects BW, FI, and FCR of broiler chickens (Udeh *et al*., 2015; Taha *et al.,* 2011). However, Thutwa *et al.* (2012) reported insignificant strain differences in BW, and FCR. And also earlier report indicates that strain has significant effect on carcass characteristics (Marcu *et al*., 2013). On the other hand, Udeh *et al.* (2015) found no difference in the yield of carcass or cuts among Ross, Arbor Acres, and Marshall Strains.

Many reports also indicate that sex affects the performance traits of chickens (Thutwa *et al*., 2012; Choo *et al*., 2014). There was no difference in FCR (Udeh *et al.,* 2015). Sex also significantly affected carcass traits (Marcu *et al.,* 2013; Pripwai *et al*., 2014; Thutwa *et al*., 2012). However, Castellini *et al.* (2014) reported that carcass characteristics were not greatly affected by sex.

Interaction effects between genotype and sex on BW, FI, and FCR were reported (Shim *et al*., 2012; Udeh *et al.,* 2015). In addition, Olawumi *et al.* (2012) reported interaction effects between strain and sex on breast, back, thigh, drumstick wing, and leg weights, while Ojedapo *et al.* (2008) reported insignificant interaction effects between strain and sex on shank, thigh, and

drumstick weights. Marcu *et al.* (2013) stated that strain had significant effects on overall carcass characteristics such as dressed, breast, drumstick, thigh, back, shank and edible giblet weights. Likewise, Pripwai *et al.* (2014) observed that sex influenced dressed weight, thigh's meat to bone ratio and wing weight. However, Udeh *et al.* (2015) reported that there was no significant difference among the carcass yields of Ross, Arbor Acres and Marshall strains and sexes of broilers. Moreover, the appearance of a broiler product, such as meat color, pH, drip loss, cooking loss and shear value, plays the major role in consumer acceptability. Many factors can influence broiler meat quality, including sex and strain (Northcutt *et al.*, 2001).

Therefore, it is necessary to evaluate and know accurately the growth performance, carcass characteristics and meat quality of different strains and genders in Thailand environment to help breeders, farmers and processors to make a decision that will benefit their business. The objectives of the present study were to compare the production performance, carcass characteristics and meat quality of Arbor Acres, Ross308, Cobb500 strains and genders, and to determine the effect of strain × gender interaction on the aforementioned traits.

Materials and methods

All animal rearing was approved by the Institutional Animal Care and Use Committee at King Mongkut's Institute of Technology Ladkrabang (CC-KMITL-/2021-007).

Experimental animal and management

Three commercial strains namely Arbor Acres, Ross308 and Cobb500 were reared in an evaporative cooling system of a poultry house at the Animal Research Farm, King Mongkut's Institute of Technology Ladkrabang**,** using both male and female day-old chicks. One thousand four hundred and forty broiler chicks, 480 chicks per strain and 240 chicks per gender were individually weighed and placed in 1.5 x 4.0-meter floor pens for the 6-week experiment. Chicks were randomly distributed to 48 pens by strain and gender, resulting in a 3 × 2 factorial arrangement with 8 pens per treatment. Each pen was equipped with two bell drinkers, and two tube feeders and was bedded with rice hulls. A 24-h lighting schedule was followed throughout the experiment. The birds were fed a commercial broiler starter diet (21.5% CP) from 1 to 21 days of age, a grower diet (19.5% CP) from 22 to 35 days of age and finisher diet (17.5% CP) from 36 to 42 days of age. Feed and water were offered ad-libitum. The experimental birds were vaccinated at the 5 and 14 days of ages

against New Castle Disease (ND), Infectious Bronchitis (IB) and Infectious Bursal Disease (IBD) with the ND+IB and IBD vaccines.

Data collection

Live performance

Chickens were weighed individually at 1, 7, 14, 21, 35 and 42 days of age. The feed given to the birds in each pen and the feed residues were recorded prior to each weighing. FI was calculated as the difference between feed given and feed left. FCR was calculated as grams FI divided by body weight. Average daily gain was calculated as grams of weight gain divided by number of days.

Carcass characteristics

At day 46, the birds were deprived of feed overnight and 2 birds were randomly selected from each pen. The selected birds were slaughtered, scaled, plucked and eviscerated. After evisceration, carcass weight, breast meat, filet, wing, thigh, drumstick, body and abdominal fat were recorded. The weight of carcass and cut parts was expressed as percentage of weight before slaughter.

Meat quality

PH measurements were taken 3 h and 24 h postmortem on the left side of the breast meat by using a spear tip glass probe connected to a portable pH meter (SG2-ELK Seven Go^{TM}, Mettler Toledo International, Shanghai). Drip loss was determined by suspending breast muscle samples in tightly sealed plastic bag filled with air and kept at 4 ℃ for 48 hours. Meat color was recorded in the L*, a* and b* mode of CIE. It was measured on the left side of breast muscle after 3 h postmortem with allowing to bloom for 30 minutes by using a handheld colorimeter (CR-400 Chromameter, Konica Minolta Sensing, Osaka, Japan). Drip loss was calculated as the percentage change in sample weight. Cooking loss was calculated from the weight loss after processing the raw breast meat to a core temperature of 70 ℃ in a water bath and expressed as a percentage of the original breast meat weight. Warner-Bratzler shear force value was taken from the cooked breast muscles and cut into 1-cm-thick slices at a traverse speed of 50 mm/min using a Texture Analyser Machine (Model EZ-SX, Shimadzu, Kyoto, Japan) attached to a 50-kg load cell.

Statistical analysis

Data were subjected to 3 × 2 factorial arrangement in completely randomized design using PROC GLM in SAS software (SAS, 2004). Student–

Newman–Keuls (SNK) method was used to compare differences between means at 5 % significant level assuming the following statistical model:

$Y_{ijk} = \mu + S_i + G_j + B_i \times G_j + \varepsilon_{ijk}$

Where,

Y_{ijk} = Dependent variables;
μ = Population mean;
S_i = Strain effect (i = 1 to 3);
G_j = Gender effect (j = 1 to 2);
$B_i \times G_j$ = Overall interaction effect;
ε_{ijk} = Residual error

Results

The effects of strain and gender on growth performance at different weeks of age are shown in Table 1 and Table 2. There were no significant ($P > 0.05$) differences in BW and ADG between the strains at weeks 1, 2, 3, and 4. However, at week 5, Arbor Acres was superior ($P < 0.05$) to Ross308 in BW and ADG, while there were no significant differences ($P > 0.05$) between Cobb500 and the other strains. At week 6, Arbor Acres had higher BW and ADG than others ($P < 0.05$). Male broilers had higher ($P < 0.01$) BW and ADG than female broilers from weeks 2 to 6. There was no significant ($P > 0.05$) interaction between strain and gender on BW and ADG of broilers throughout the experimental period. FI and FCR at weeks 1, 2, 3, 4 and 5 were also not significantly ($P > 0.05$) affected by strain, but ($P < 0.05$) FI and FCR at week 6 were. FI was higher in Cobb500 than Ross308, while there were no differences ($P > 0.05$) between Cobb500 and Arbor Acres and between Arbor Acres and Ross308. Arbor Acres and Ross308 utilized feed more efficiently ($P < 0.05$) than Cobb500, while there were non-significant differences ($P > 0.05$) between Arbor Acres and Ross308. No effect of gender ($P > 0.05$) on FI and FCR at week 1, but male broilers consumed more feed and had better FCR ($P < 0.05$) than female broilers at weeks 2, 3, 4, 5, and 6. No interactions ($P > 0.05$) were observed between strain and gender for FI and FCR throughout the rearing period.

Table 1. Effect of strain and gender on body weight and average daily gain

Trait	Strain (S)			Gender (G)		P value		
	Arbor Acres	Ross308	Cobb500	male	female	S	G	S x G
Body weight (g)								
Week 1	191.96	190.78	188.79	191.37	189.64	0.198	0.231	0.510
Week 2	492.79	494.13	491.03	502.46	482.84	0.848	<0.001	0.478
Week 3	963.37	968.95	952.88	969.95	953.51	0.073	0.005	0.432
Week 4	1696.51	1676.41	1657.91	1794.41	1559.47	0.187	<0.001	0.121
Week 5	2223.27^{a}	2164.28^{b}	2201.78^{ab}	2368.46	2024.43	0.015	<0.001	0.208
Week 6	3027.75^{a}	2931.13^{b}	2955.34^{b}	3272.79	2670.02	0.013	<0.001	0.499
ADG (g/d)								
Week 1	27.42	27.25	26.97	27.34	27.09	0.198	0.231	0.510
Week 2	35.20	35.30	35.07	35.89	34.49	0.848	<0.001	0.478
Week 3	45.87	46.14	45.38	46.19	45.41	0.073	0.005	0.432
Week 4	60.59	59.87	59.21	64.089	55.70	0.188	<0.001	0.122
Week 5	63.52^{a}	61.84^{b}	62.91^{ab}	67.67	57.84	0.015	<0.001	0.208
Week 6	72.09^{a}	69.79^{b}	70.37^{b}	77.92	63.57	0.013	<0.001	0.499

Table 2. Effect of strain and gender on feed intake and feed conversion ratio

Trait	Strain (S)			Gender (G)		P value		
	Arbor Acres	Ross308	Cobb500	male	female	S	G	S x G
Feed intake (g)								
Week 1	176.81	177.08	171.52	176.04	174.24	0.091	0.431	0.076
Week 2	440.17	449.45	432.98	419.78	461.96	0.288	<0.001	0.777
Week 3	1312.58	1328.25	1347.47	1365.41	1293.46	0.221	<0.001	0.189
Week 4	2549.92	2502.50	2542.73	2633.10	2430.33	0.247	<0.001	0.784
Week 5	4263.18	4236.03	4286.21	4361.41	4162.20	0.745	<0.001	0.2923
Week 6	5887.09^{ab}	5740.09^{b}	6048.57^{a}	6035.81	5748.03	0.019	0.002	0.799
Feed conversion ratio								
Week 1	0.92	0.93	0.91	0.92	0.92	0.240	0.880	0.094
Week 2	0.90	0.91	0.89	0.84	0.96	0.609	<0.001	0.984
Week 3	1.36	1.37	1.42	1.41	1.36	0.058	0.008	0.437
Week 4	1.51	1.52	1.54	1.47	1.57	0.471	<0.001	0.071
Week 5	1.92	1.97	1.95	1.84	2.06	0.297	<0.001	0.119
Week 6	1.96^{b}	1.98^{b}	2.06^{a}	1.85	2.15	0.021	<0.001	0.446

The male broilers had higher carcass weight, breast weight, fillet weight, wing weight, thigh weight, drumstick weight, bone weight than the females ($P < 0.01$). In contrast, the female broilers had higher percentage of fillet and

abdominal fat than the male broilers (P<0.01). No effect of gender (P>0.05) was observed on the weight of abdominal fat, percentages of breast, wing, thigh, drumstick and bone. No interactions (P>0.05) were observed between strain and gender for any of the carcass characteristics variables.

Table 3. Effect of strain and gender on carcass characteristics

Trait	Strain (S)			Gender (G)		P value		
	Arbor Acres	Ross308	Cobb500	male	female	S	G	S x G
Slaughter wt. (kg)	3.13[a]	3.03[b]	3.04[b]	3.37	2.77	0.015	<0.001	0.669
Carcass wt. (kg)	2.56	2.49	2.50	2.75	2.29	0.274	<0.001	0.291
Carcass composition								
Breast (kg)	0.69	0.67	0.66	0.73	0.61	0.134	<0.001	0.245
Fillet (kg)	0.13	0.12	0.12	0.13	0.12	0.108	<0.001	0.738
Wing (kg)	0.27	0.26	0.26	0.29	0.24	0.295	<0.001	0.832
Thigh (kg)	0.42	0.41	0.42	0.46	0.34	0.862	<0.001	0.529
Drumstick (kg)	0.28	0.28	0.28	0.39	0.25	0.658	<0.001	0.252
Bone (kg)	0.40	0.39	0.40	0.44	0.36	0.424	<0.001	0.322
Abdominal fat (kg)	0.06	0.05	0.05	0.05	0.05	0.583	0.668	0.534
Breast (%)	22.08	22.10	21.84	21.84	22.18	0.868	0.461	0.207
Fillet (%)	4.16	4.16	4.00	3.95	4.32	0.768	<0.001	0.449
Wing (%)	8.53	8.52	8.56	8.50	8.57	0.975	0.710	0.878
Thigh (%)	13.31	13.68	13.78	13.55	13.63	0.422	0.801	0.413
Drumstick (%)	9.02	9.18	9.14	9.16	9.06	0.786	0.608	0.131
Bone (%)	12.92	13.01	13.12	12.99	13.04	0.825	0.869	0.203
Abdominal fat (%)	1.81	1.72	1.75	1.56	1.96	0.849	0.004	0.621

There were no significant differences in meat quality traits for pH_3 and pH_{24}, drip loss and cooking loss ($P > 0.05$) between broiler strains. No significant differences were found in drip loss, cooking loss and shear force value between genders, except for pH_3 ($P < 0.05$) and pH_{24} ($P < 0.01$) which were influenced by gender, as male broilers had higher value than females. For meat color, breed and gender had no effect ($P > 0.05$) on lightness, redness, and yellowness, except for yellowness, which decreased in males and increased in females ($P < 0.05$). An interaction effect between breed and gender was found for lightness and redness. Arbor Acres female had lighter color than Arbor Acres male, Cobb500 female, Cobb500 male, and Ross308 female. Breast meat of Cobb500 female had higher redness value than Arbor Acres male, Ross308 female ($P < 0.01$) and Cobb500 male ($P < 0.05$). However, no interactions were observed between strain and gender ($P > 0.05$) for pH_3, pH_{24}, drip loss, cooking loss, and shear force value.

Table 4. Effect of strain and gender on meat quality

Trait	Strain (S)			Gender (G)		P value		
	Arbor Acres	Ross308	Cobb500	male	female	S	G	S x G
pH_3	6.00	6.02	6.01	6.04	5.98	0.791	0.011	0.455
pH_{24}	6.01	6.01	5.97	6.03	5.96	0.476	0.006	0.770
Meat color								
L* (lightness)	53.46	54.59	54.61	54.41	54.03	0.140	0.472	<0.001
a* (redness)	0.43	0.47	0.76	0.38	0.73	0.430	0.136	0.019
b*(yellowness)	7.62	8.24	8.52	7.56	8.70	0.399	0.043	0.585
Drip loss (%)	1.49	1.83	1.57	1.62	1.64	0.154	0.899	0.221
Cooking loss (%)	12.58	14.10	12.36	12.51	13.52	0.188	0.231	0.839
Shear force (kg)	4.92^b	4.96^b	3.84^a	4.749	4.40	0.023	0.329	0.847

Discussion

In this study, strain was not significant ($P > 0.05$) affected on the BW and ADG at weeks 1, 2, 3, and 4, which is consistent with Rokonuzzaman *et al.* (2015) who found no significant difference ($P > 0.01$) in BW of Cobb500, Hubbard Classic and Arbor Acres at weeks 1, 2 and 4 and in ADG at weeks 1, 2, 3 and 4. The BW and ADG at 5 and 6 weeks of age were significantly different ($P < 0.05$). Arbor Acres was superior to Ross308 and Cobb500 but there was no significant difference ($P > 0.05$) between Cobb500 and Ross 308. These results could be due to genetic variation among the different strain (Lopez *et al*., 2011). Suchon *et al.* (2017) also found the genetic variation among strains of broilers, but they reported that the BW and ADG of Ross308 were better than Arbor Acres and CobbMX. This result is also in agreement with the findings of Udeh *et al.* (2015) who reported that Arbor Acres had higher BW and ADG than Ross308 ($P < 0.05$). This is in contrast to the report of Ciurescu and Grosu (2011) that BW and ADG of Arbor Acres, Cobb500 and Ross 308 were similar ($P > 0.05$).

In this result, strain did not affect FI and FCR at weeks 1, 2, 3, 4 and 5, but FI and FCR at week 6. This is almost the same result as Livingston *et al.* (2020) who reported strain had no effect on FI at weeks 2, 3, 4 and 5 and FCR at weeks 1, 2, 4 and 5 and also Rokonuzzaman *et al.* (2015) reported that strain had an effect on FI at weeks 1, 2 and 4 in broilers. However, Suchon *et al.* (2017) reported that FI of Arbor Acres, Ross308 and Cobb500 were similar ($P > 0.05$) but FCR of Cobb500 was better than Arbor Acres and Ross308 ($P < 0.05$) at 6 weeks of age.

In the present study, it was found that gender had no effect on BW, ADG, FI and FCR at week 1 but there were statistical differences at weeks 2, 3, 4, 5 and 6. Male broilers performed better than females as evidenced by higher FI,

BW and better FCR. This effect is well documented in the literature (Brewer *et al.*, 2012; Zuidhof *et al.*, 2014). These results are in agreement with the reports of Livington *et al*. (2020) that male broilers had higher BW and FI but lower FCR ($P < 0.01$) than females at 2-6 weeks of age. Engku Azahan *et al.* (2007) found that Arbor Acres males were superior to Arbor Acres females in terms of growth parameters such as BW, FI and FCR at 6 weeks of age. Zerehdaran *et al.* (2004) described that the differences between genders in a trait cannot be attributed to a single factor; factors such as greater competition for feed, aggressive behavior of males, social dominance, different nutritional requirements, and the influence of hormones on growth and fatness all play a role.

In this study, no significant interaction ($P > 0.05$) was found for BW, ADG, FI and FCR in relation to strain and gender. A similar result was reported by Nascimento *et al.* (2018). These results are in contrast to the findings of Suchon *et al.* (2017) who reported that there was no significant interaction ($P > 0.05$) between strain and gender on FI and FCR, but significant effect was found on BW and ADG at 6 weeks of age. And also, Livington *et al.* (2020) found no interaction effect on BW at weeks 1, 4, 5 and 6, FC at weeks 1, 2, 4, 5 and 6, and FCR at weeks 1, 2, 3, 4, 5 and 6.

Carcass characteristics showed no effect of strain on weight and percentage of carcass parts. The results are in agreement with the report of Ciurescu and Grosu (2011). There were no significant differences ($P > 0.05$) among Arbor Acres, Ross308 and Cobb500 in carcass yield, breast, thigh and drumstick. The same result was found by Suchon *et al.* (2017) who reported that the percentage of dressing, thigh and drumstick, breast, filet and wing had no significant differences ($P>0.05$) among Arbor Acres, Ross and Cobb at 6 weeks of age. However, these results do not agree with those of Saijai and Damnern (2020) who reported that carcass, wing, breast, filet, thigh and drumstick were significantly different between Arbor Acres, Ross308, Cobb500 and Hubbard.

In this study, gender was found to affect carcass weight. Male had higher carcass weight, breast weight, fillet weight, wing weight, thigh weight and drumstick weight than females ($P < 0.01$) and females had higher percentage of fillet than males ($P < 0.01$). This result agrees with that of Ikusika *et al.* (2020) who reported that gender had an effect on dressing weight, drumstick weight and thigh weight ($P < 0.01$) and Tanachai *et al.* (2017) reported that females had higher weight and percentage of fillet than females ($P < 0.05$), in contrast they reported that gender had no effect on weight and percentage of carcass, thigh and drumstick, breast, and wing ($P > 0.05$). Nascimento *et al.* (2018) also found an effect of gender on carcass weight, breast weight and thigh weight ($P < 0.01$). In contrast, Suchon *et al.* (2017) reported that gender had no

effect on dressing percentage, thigh, drumstick, breast, fillet and wing weight ($P > 0.05$). In this study, it was found that there was no association ($P > 0.05$) between strain and gender in any of the carcass traits assessed at 6 weeks. This is in agreement with the report of Nascimento *et al.* (2018) who observed insignificant interaction effect ($P > 0.05$) for carcass traits.

In this study, no significant effect ($P > 0.05$) was found for pH_3 and pH_{24}, drip loss and cooking loss with respect to strain and strain-sex interaction. Strain had an effect on shear value and female broilers had lower pH_3 and pH_{24} than males ($P < 0.05$) while female broilers had higher b* than males ($P < 0.05$). This is in agreement with the report of Lopez *et al.* (2011) who observed an insignificant effect ($P > 0.05$) of strain and breed-sex interaction on cooking loss and shear value, but they also reported that female broilers had lower pH_{24} ($P < 0.01$) than females and females had higher b* value than males ($P < 0.05$), the same result as in this study. The interaction effect of breed and gender on L* ($P < 0.01$) and a* values ($P < 0.05$) found in this study did not agree with Lopez *et al.* (2011) who reported that there was no interaction effect on L* and a* values ($P > 0.05$). Shear force value was affected by strain, with the breast meat of Cobb500 being more tender than that of Ross308. This is in agreement with the report of Ristic (2005) who reported that the Ross308 broilers had a higher share value of breast than Cobb500.

In summary, Arbor Acres had higher body weight, ADG, and FCR compared to the Ross308 and Cobb500 strains. However, the strains did not differ in carcass characteristics, pH at 3 and 24 h postmortem, lightness, redness, drip loss and cooking loss. However, strain did have an effect on shear force value. Males had better BW, ADG, FE, FCR, carcass, breast, fillet, wing, thigh and drumstick weights. Cobb500 had the lowest shear value and males had lower pH at 3 and 24 hours postmortem and b* value. No strain-sex interaction was observed for performance and carcass traits. Interaction effect between breed and gender was found in lightness and redness colors.

Based on the results of this study, Arbor Acres broilers should be recommended in Thailand because they had higher production performance after 6 weeks and rearing sex-segregated flocks could be beneficial. Some smallholders wish to sell their birds at a live weight of about 2.0 kg for roasting. In this case, both Arbor Acres and Ross308 are recommended.

Acknowledgements

The authors would like to acknowledge financial support provided by Thai Foods Group Public Company Limited, Thailand. We thank Faculty of Agricultural Technology and Faculty of Industrial Education and Technology, King Mongkut' s Institute of Technology Ladkrabang, for instrumental support of this work.

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(Received: 13 September 2021, accepted: 30 January 2022)