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Evaluation of the body weight and laying performance of diallel crossed Korean native chicken layers from hatch to 40 weeks of age

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Abstract

The current experiment was conducted to evaluate the effect of diallel crossbreeding on the body weight and laying performance of Korean native chicken from hatch to week 40. A total of 1,000 one-day-old chicks were allotted to 10 cages per crossbreeding treatment with 10 birds per cage on a random basis and then raised until 16 weeks and subsequently moved to layer battery cages and raised until 40 weeks. Ten crossbred treatments (YC, YD, YF, YK, CD, CF, CK, DF, DK, FK) that were obtained from the diallel crossbred of five pure lines were used in the current experiment. The body weight and mortality were measured biweekly from hatching to week 20 and every four weeks from week 20 to week 40. The number of eggs was measured daily. YC and YD crossbreeds showed a higher body weight ($p < 0.05$) and FK crossbreed showed a lower body weight ($p < 0.05$) during the whole experimental period. The week 20 weight range was 1,501 to 1,729 g and the week 40 weight range was from 1,829 to 2,179 g. Earlier onset of egg-laying was noted in the YC and YD groups whereas late onset was observed for the DF and DK groups. YK reached its peak earliest at week 25 with 89.15% while the DK crossbreed attained its peak at week 36 with 89.69%. The YC and YD crossbreeds showed the improved body and egg-laying performance. Conclusively, there are variations in the body weight and laying performance of Korean native chickens with diallel crossing.

Key words: crossbreed, diallel cross, heterosis, Korean native chicken, layer

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Introduction

Korean native chicken (KNC) constitute a number of domestic fowl species that have been raised in Korea for at least seven generations without mixing with other breeds. They have a clear origin and unique genetic characteristics. They can be distinguished based on their plumage color into five lines namely reddish-brown, yellowish-brown, black, white, and grayish-brown (NIAS, 2012). Due to natural selection, native chicken varieties are considered to be more disease-resistant and highly adaptable to prevailing local environmental conditions as compared to commercial breeds (Zhang et al., 2014). Regardless of their reported desirability and health benefits, the productive and growth performance of Korean native chickens has been reported to be low (Ogola et al., 2021). Previous studies have reported KNC could produce 188 eggs per year and an average egg weight of 53 g (Kim et al., 2012). Productive performance of approximately 65% on hen-day egg production (HDEP) basis as at week 64, which is quite low egg productivity compared to commercial layer strain have been reported (Kim et al., 2012).

A number of genetic approaches could be employed to improve productivity including diallel crossbreeding. It involves a set of crosses between homozygous lines and it is used for quantifying genetic effects such as general combining ability, specific combining ability, reciprocal line effect, and heterosis (Onofri et al., 2021). The general combining ability has been defined as the variance from the average ability of two-parent stocks in crossbreeding by interacting genes with additive effects (Sprague and Tatum, 1942). According to Onofri et al. (2021), the specific combining ability is the effect that combinations give unanticipated effects with positive and negative directions. The certain combining ability is regarded as the non-additive effect concluding dominance and epistatic interaction. The reciprocal effect is the discrepancy between crosses that consisted of the same homozygous lines but reversed paternal and maternal lines. The reciprocal effect is important to decide the parental lines showing superior performances. The heterosis effect is one of the well-known genetic methods that first-generation hybrids born by crossbreeding two pure species often exhibit superior performances than the pure species of both plants and animals (Warren, 1927).

Previous studies in the poultry field suggest that a three-line White Leghorn inbreed cross exhibited superior performance than the two-line cross and five lines with Single Combed White Leghorn half diallel cross improves egg productivity and egg weight (Ohh et al., 1980; Abplanalp et al., 1984). Recent KNC layer experiments also suggest that crossbred layers reported a higher egg weight (Cho et al., 2018; Hong et al., 2019). Therefore, the objective of this experiment is to compare the heterosis effect of crossbred KNC layers with half diallel method on body weight, daily hen-day egg production, age at started egg-laying, and age at sexual maturity by using 5 different KNC pure-line layers from hatch to week 40.

Materials and Methods

The specifications of the birds in this experiment and the experimental conditions were approved by the by the Animal Ethics Committee of Chungnam National University (202109A-CNU-112). The experiment was conducted at the Cheongyang Research Unit of Chungnam National University.

Experimental design

We carried out a 5 × 5 half diallel cross with 5 pure lines that consisted of one KNC (Y), two Korean Rhode Island Chicken (C, D), and two Korean White Leghorn Chicken (E, F) to make 10 crossbred strains that were denoted as YC, YD, YF, YK, CD, CF, CK, DF, DK, FK. A total of 1,000 one-day-old female chicks were used. Each treatment had 100 female chicks that were allotted into 100 battery cages (76 × 61 × 46 cm^3) with 10 birds per cage from hatch to 16 weeks. After the end of the rearing period, the birds were moved to battery cages (60 × 25 × 45 cm^3) with 4 birds per cage with 25 replicates to measure the daily hen-day egg production, age at started egg-laying, and age at sexual maturity. Water was supplied on an *ad-libitum* basis. Diets were provided on a restricted basis based on their body weight following Korean Feeding Standard for Poultry (NIAS, 2018). The diet formulas are presented in Tables 1 and 2.

Table 1. Composition of the experimental diets (g·kg^{-1}, as-fed basis) in the growing phase.

Ingredient	Diets		
	Week 0 - 5	Week 6 - 10	Week 11 - 15
Corn	60.40	65.30	70.40
Soybean meal	32.50	26.90	21.10
Wheat bran	1.00	1.50	2.00
Corn gluten meal	1.00	1.50	2.00
Soybean oil	1.50	1.50	1.50
Dicalcium phosphate	1.50	1.30	1.10
Limestone	1.10	1.05	1.00
Salt	0.25	0.25	0.25
L-lysine	0.05	0.05	0.05
DL-methionine	0.20	0.15	0.10
Vitamin-mineral premix[z]	0.50	0.50	0.50
Chemical composition			
ME (kcal·kg^{-1})	3,059	3,123	3,187
CP (%)	20.30	18.60	16.70

ME, metabolizable energy; CP, crude protein.

[z] Vitamin and mineral mixture provided the following nutrients per kg of diet: vitamin A, 24,000 IU; vitamin D3, 6,000 IU; vitamin E, 30 IU; vitamin K, 4 mg; thiamin, 4 mg; riboflavin, 12 mg; pyridoxine, 4 mg; folacin, 2 mg; biotin, 0.03 mg; vitamin B8 0.06 mg; niacin, 90 mg; pantothenic acid, 30 mg; Fe, 80 mg (as $FeSO_4 \cdot H_2O$); Zn, 80 mg (as $ZnSO_4 \cdot H_2O$); Mn, 80 mg (as $MnSO_4 \cdot H_2O$); Co, 0.5 mg (as $CoSO_4 \cdot H_2O$); Cu, 10 mg (as $CuSO_4 \cdot H_2O$); Se, 0.2 mg (as Na_2SeO_3); I, 0.9 mg (as $Ca(IO_3) \cdot 2H_2O$).

Table 2. Composition of the experimental diets (g·kg^{-1}, as-fed basis) in the laying phase.

Ingredient	Diets	
	Week 16 - 30	Week 31 - 40
Corn	59.10	57.90
Wheat bean	2.50	6.25
Soybean meal	21.00	18.30
Corn gluten meal	5.00	5.00
Soybean oil	0.50	0.50
Dicalcium phosphate	1.20	1.00
Limestone	9.10	9.50
Salt	0.25	0.25
L-lysine	0.10	0.10
DL-methionine	0.25	0.20
Vitamin-mineral premix[z]	1.00	1.00
Chemical composition		
ME (kcal·kg^{-1})	2,859	2,805
CP (%)	18.20	17.30

ME, metabolizable energy; CP, crude protein.

[z] Vitamin and mineral mixture provided the following nutrients per kg of diet: vitamin A, 24,000 IU; vitamin D3, 6,000 IU; vitamin E, 30 IU; vitamin K, 4 mg; thiamin, 4 mg; riboflavin, 12 mg; pyridoxine, 4 mg; folacin, 2 mg; biotin, 0.03 mg; vitamin B8 0.06 mg; niacin, 90 mg; pantothenic acid, 30 mg; Fe, 80 mg (as $FeSO_4 \cdot H_2O$); Zn, 80 mg (as $ZnSO_4 \cdot H_2O$); Mn, 80 mg (as $MnSO_4 \cdot H_2O$); Co, 0.5 mg (as $CoSO_4 \cdot H_2O$); Cu, 10 mg (as $CuSO_4 \cdot H_2O$); Se, 0.2 mg (as Na_2SeO_3); I, 0.9 mg (as $Ca(IO_3) \cdot 2H_2O$).

Measurements

Body weight, number of eggs, and mortality were measured for comparing the ability of each treatment. Body weights of the birds were measured biweekly from hatch to 20 weeks. From week 20 to week 40, body weights were measured every four weeks. The number of eggs is measured daily from birds are started laying an egg. Hen-day egg production was calculated by the measured daily egg-laying data on weekly basis. Additionally, two different egg-laying days were recorded: age at started egg-laying that first egg-laying day from each treatment and age at sexual maturity that first day of 50% pullets laying eggs for two days continuously in one treatment.

Statistical analysis

Collected data was analyzed using the one-way ANOVA technique, complete randomized design by using the SPSS software package (Version 26; IBM SPSS 2019, Chicago, IL, USA). Tukey's multiple range test was used to separate the means between experimental groups when significant differences were noted.

Results and Discussion

The recorded body weights from hatch to week 40 is presented in Tables 3 and 4. Significant influences from the initial body weight were noted and this tendency are maintained until the current experiment was finished. YC and YD crossbreeds showed a higher body weight ($p < 0.05$) compared to the other crossbreed during the whole experimental period. On the other hand, the FK crossbreed shows a lower body weight ($p < 0.05$) during the entire experimental period. The body weights of the birds in this experiment at week 20 ranged from 1,501 to 1,729 g. The current weights were slightly lower than the body weight range of the previous KNC layer experiment from 1,690 to 1,861 g (Hong et al., 2012) and the weights of another KNC broiler experiment from 1,682 to 2,127 g (Cho et al., 2018). Furthermore, the range of body weight in this experiment at week presents from 1,829 to 2,179 g which were lower than the previous KNC study results from 2,186 to 3,784 g (Kang et al., 1997). Those body weight gaps could be caused by the quality and specification management of feed or by comparing the layer experiment and broiler experiments.

Age at the start of egg-laying and age at sexual maturity are shown in Table 5. YC and YD treatments exhibit the age at starting the laying egg early on day 128. On the other hand, DF and DK treatments exhibit later age at the onset of laying at day 142. YC and YD treatments appeared to have an improved age of starting egg-laying. However, the age at sexual maturity appears a little different trend with the age at starting the laying egg. YD treatment shows the age at sexual maturity on day 158 as a first and YC on day 159 as a second. CD treatment exhibits the latest age at sexual maturity on day 175. Compared to the previous KNC crossbreed age at started egg-laying, on day 166 (Lee, 1995), YC and YD treatments performed superior but FK, CF, YF, and CD treatments performed similarly or inferior. The results can be explained that not only the environmental condition and the management but also the heterosis improves the age of sexual maturity which agreed with previous studies that crossbreeding could improve the age of sexual maturity (Cheong and Chung, 1985). Some treatments showing maximum or minimum values could be caused by the specific combining ability that specific crossbreeding could result to (Onofri et al., 2021). Thus, less performing crossbreed should be removed to reduce the specific combining ability in a negative way.

Table 3. Body weight of crossbred Korean Native Pullets from hatch to week 16.

Week	YC	YD	YF	YK	CD	CF	CK	DF	DK	FK	SEM	p-value
Initial	37.59	38.18	38.42	38.91	37.32	37.88	38.30	39.35	37.47	37.79	0.101	< 0.001
2	138.42	142.60	128.17	130.79	131.36	127.51	129.30	126.77	127.77	117.49	0.523	< 0.001
4	338.01	338.21	323.65	316.98	318.35	319.74	324.65	320.11	314.59	298.35	1.184	< 0.001
6	645.89	635.62	572.42	557.92	615.34	595.15	590.28	592.71	571.11	535.72	2.158	< 0.001
8	855.31	843.34	766.29	742.89	823.72	807.88	782.59	784.76	752.33	718.20	2.643	< 0.001
10	1,053.65	1,040.52	974.60	972.83	1,030.37	1,004.35	994.24	979.05	974.96	925.90	2.960	< 0.001
12	1,172.46	1,158.26	1,062.72	1,087.34	1,154.30	1,114.65	1,137.11	1,090.31	1,108.32	1,042.72	3.694	< 0.001
14	1,236.02	1,239.73	1,130.08	1,276.86	1,223.51	1,191.40	1,205.34	1,156.12	1,170.30	1,097.36	11.902	0.021
16	1,341.22	1,331.19	1,213.89	1,245.45	1,274.48	1,260.27	1,278.26	1,235.35	1,244.00	1,159.30	6.601	< 0.001

SEM, standard error of the mean.

Table 4. Body weight of crossbred Korean Native Pullets from week 16 to week 40.

Week	YC	YD	YF	YK	CD	CF	CK	DF	DK	FK	SEM	p-value
16	1,341.22	1,331.19	1,213.89	1,245.45	1,274.48	1,260.27	1,278.26	1,235.35	1,244.00	1,159.30	6.601	< 0.001
18	1,465.43	1,609.70	1,321.13	1,355.05	1,393.30	1,388.73	1,388.75	1,358.56	1,351.12	1,254.58	6.931	< 0.001
20	1,613.20	1,600.37	1,599.16	1,689.75	1,534.52	1,431.95	1,696.92	1,729.06	1,501.09	1,518.33	7.604	< 0.001
24	1,696.92	1,729.06	1,501.09	1,518.33	1,613.20	1,600.37	1,599.16	1,689.75	1,534.52	1,431.95	8.469	< 0.001
28	1,784.66	1,776.62	1,603.03	1,629.23	1,738.29	1,652.96	1,709.31	1,618.19	1,592.97	1,500.36	9.364	< 0.001
32	1,829.91	1,834.96	1,686.03	1,688.64	1,795.40	1,693.03	1,759.50	1,639.91	1,632.17	1,539.68	10.212	< 0.001
36	2,171.52	2,154.49	1,934.03	1,896.76	2,093.20	1,981.46	2,019.71	2,007.08	1,877.11	1,823.99	10.342	< 0.001
40	2,179.87	2,159.91	1,939.20	1,902.03	2,098.73	1,987.44	2,025.39	2,011.55	1,882.62	1,829.89	10.972	< 0.001

SEM, standard error of the mean.

Table 5. Age at started egg-laying and age at sexual maturity of crossbred Korean native chicken.

Laying performance	YC	YD	YF	YK	CD	CF	CK	DF	DK	FK
Age at started egg-laying[y] (day)	128	128	135	128	136	131	137	142	142	135
Age at sexual maturity[z] (day)	159	158	170	157	175	169	159	162	161	167

[y] First egg-laying day from each treatment.

[z] First day of 50% pullets laying eggs for two days continuously in one treatment.

The egg production rates are exhibited in Table 6. YK crossbreed reaches the peak at week 25 with 89.15%. After week 25, all crossbreeds showed slight decreases, however, DK crossbreed peaked later at week 36 with 89.69%. Compared to the previous studies, the egg production rate did not show a similar trend as recorded by Kang et al. (2012) showing that that from week 20 to 24, the HDEP could rise from 62.4 to 78.8%, and from week 36 to 40 to elevate from 52.1 to 68.1% (Kang et al., 2012) but this experiment indicates a higher peak and dramatic decreases. These differences could be caused by the specification management of feed or the failure of management details such as controlling light.

Table 6. Egg production of crossbred Korean native chickens from the starting age of laying to week 40.

Week	CD	CF	CK	DF	DK	FK	YC	YD	YF	YK
19	0.00	0.38	0.00	0.00	0.00	0.00	1.60	2.25	0.00	2.33
20	0.56	1.79	0.63	0.00	0.00	0.81	3.80	4.98	1.52	4.30
21	3.90	6.17	5.02	1.81	4.44	2.44	12.31	9.63	4.41	18.59
22	8.35	21.75	27.79	7.78	23.81	13.64	35.26	32.42	21.58	40.09
23	20.22	40.26	47.41	22.97	44.44	32.31	48.94	50.08	42.71	56.22
25	49.71	70.63	64.21	56.11	68.88	62.02	75.45	72.41	61.22	89.15
26	59.30	76.57	67.97	64.37	72.28	60.50	77.23	79.15	66.09	87.88
27	63.99	76.89	64.81	65.75	65.14	61.68	80.21	79.47	65.31	86.44
28	60.27	71.91	61.50	60.24	64.29	58.49	78.57	74.38	60.28	83.18
29	61.84	71.95	70.91	66.20	69.78	51.26	78.26	68.86	62.89	77.63
30	63.67	72.82	71.77	66.80	67.22	57.31	82.45	72.87	66.03	77.07
31	56.53	69.51	69.88	61.77	65.02	53.45	76.09	69.02	63.76	73.50
32	47.35	59.41	59.90	53.12	53.11	47.23	65.84	61.48	53.31	62.78
33	48.42	57.14	57.46	58.77	64.44	47.24	55.93	53.29	41.95	29.19
34	51.02	58.44	59.03	62.93	61.43	51.79	58.81	54.41	42.25	29.34
35	70.50	83.77	81.95	89.51	83.81	77.11	76.75	78.17	57.60	49.31
36	75.14	83.77	83.05	89.69	85.56	80.03	80.85	80.90	60.79	49.77
37	72.36	83.93	80.53	89.15	84.44	78.73	80.85	80.90	58.51	51.31
38	61.22	69.16	67.19	73.78	72.70	69.32	66.41	72.55	51.06	44.55
39	45.83	45.78	51.02	55.88	61.59	52.76	50.15	66.29	37.99	40.71
40	46.38	44.64	49.61	53.16	57.30	52.44	50.00	68.38	36.63	41.47

Conclusion

This experiment was conducted to estimate the effect of the KNC layer crossbreeds with the half-diallel cross method on body weight and egg performances from hatch to week 40. YC and YD crossbreeds show improved growth performances and egg-laying performances compared to the other treatments. YC and YD treatment needed to be analyzed with other genetical methods to make an improved offspring with follow-up research. Conclusively, there are variations in the body weight and laying performance of Korean native chickens with diallel crossing. The current results could be used as a database for future KNC layer experiments.

Conflict of Interests

No potential conflict of interest relevant to this article was reported.

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