IMPROVEMENT AND UTILIZATION OF GENETIC RESOURCES IN NATIVE CHICKEN: RECIPROCAL CROSS BETWEEN TAIWAN COUNTRY CHICKEN AND SINGLE COMB WHITE LEGHORN

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Summary

Reciprocal crosses were conducted between three strains of Taiwan Country chickens, developed in the National Chung-Hsing University, and two strains of Single Comb White Leghorns, developed in the Taiwan Livestock Research Institute. Traits studied were growing performances, laying performances, egg quality traits and traits concerning disease resistance, including resistance to Marek's disease virus and immune responses to Newcastle disease virus vaccine and to sheep red blood cell. Results indicated that laying performances of Taiwan country chickens were much inferior to White Leghorns, but they matured earlier, their eggs had better shell strength and larger proportion of yolk, and their general disease resistance was much better than White Leghorns. Heterosis were found in laying performances and egg quality traits. The heterosis in laying traits was so large that the hybrid laid as many eggs and as large eggs as did pure strains of White Leghorns. Strategies on the improvement of native chickens and the utilization of genetic merits of native chickens were also discussed.
(*Key Words:* Native Chicken, Reciprocal Cross, Egg Quality, Disease Resistance)

Introduction

In recent years, more than 65% of chickens consumed in Taiwan were "country" chickens (DAF, 1988) and they comprised almost 90% of chickens sold to households. This chicken is an upgraded native chicken with colored, generally red, plumage, blue shank and a large, erect single comb. The consumer in Taiwan would pay a higher price for this chicken due to the "meat quality". Because of its importance, this chicken has been studied in our laboratory since 1982. Compared to the exotic imported white-plumage broiler, this chicken grows very slowly and has a poor feed efficiency. They are marketed around 15 weeks of age, when they show sexually matured appearance, with average body weight of 2 kg and feed conversion around 3.0 (Fan and Lee, 1984; Lee and Huang, 1985). We have suggested that the best way to improve feed efficiency is to hasten sexual maturity (Lee and Huang, 1988). Besides, the breeder of the country chicken is also poor in producing hatching eggs, as suggested by the commercial breeders and by our own data. However, it is said, by the farmers, that the country chicken has better disease resistance, especially to the local disease such as Leucocytozoonosis.

Taiwan is the most densely populated country (more than 500 people per km^2) in the whole world. Furthermore, two thirds of the island is mountainous and not suitable for farming. Chicken farms are very close to each other and this and the warm-humid climate together have made the control of diseases the most important issue in the chicken industry. The imported exotic breeds of chicken, such as "white broilers" and White Leghorns, are very efficient birds in producing chicken meat and eggs, but they are also vulnerable to diseases and careful hygienic measures should be taken to ensure maximum

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production efficiency and the safety of poultry products.

In this study, the country chicken was compared with White Leghorns and their reciprocal crosses. The growing and laying performances and some traits related to disease resistance were studied in a series of experiments. The purposes are to study (1) if there is any genetic resistance to diseases in the country chicken, (2) how much differences are there in egg production traits between the two breeds, (3) how to utilize native chickens to improve the disease resistance in exotic breeds, and (4) how to use White Leghorns to improve egg production traits in native chickens.

Materials and Methods

Genetic Stocks

Country chickens, Single-Comb White Leghorns, and their reciprocal crosses were used. Country chickens were strains developed in our laboratory in National Chung-Hsing University which included strains Y, L1, L2, B and S. Strains B and S were selected strains for comb size at 12 to 16 weeks of age. Strains Y, L1 and L2 were selected not only for comb size but also for egg production before 40 weeks of age. Strains B, S, L1 and L2 had similar genetic background but strain Y was from a different source. Foundation stocks of strains B and L2 were birds with better body conformation. Those of strain S were with smaller body size. Single-Comb White Leghorn strains P and E were developed in the Taiwan Livestock Research Institute. Both strains were formed in 1976 by collecting commercial layers in Taiwan. Strain P was selected for egg production before 40 weeks of age and strain E was selected for egg weight at 40 weeks of age. In this paper, Breeds C, L, C*L and L*C are also used to denote the Country chicken, White Leghorn, Country* Leghorn (sired by the country chicken) and Leghorn*Country (sired by the White Leghorn), respectively.

Growing and Laying Performances

Strains Y, L1 and L2 of Country chickens, strains P and E of White Leghorns and reciprocal crosses between the two breeds were studied in two hatches. The birds were hatched at the 12th of December in 1985 and at the 1st of May in 1986, respectively, and the number of birds used is shown in table 1. All chicks were wingbanded and reared in floor pens to 16 weeks of age, and then moved to single-bird wired cages. Birds were brooded for the first two weeks, and then raised under natural light to 20 weeks of age. Artificial lights were supplemented after 20 weeks of age to give a constant 14 hours of photoperiod. Compositions of diets are shown in table 2. Newcastle disease vaccinations were done at 4 days (B1 strain), 2 weeks (La Sota strain), 4

TABLE 1. NUMBER OF BIRDS USED IN THE STUDY OF GROWING AND LAYING PERFORMANCES

						Country * Leghorn						Leghorn * Country					
	Country			Leghorn		Y * P	Y * E	L1 * P	L1 * E	L2 * P	L2 * E	P * Y	P * L1	P * L2	E * Y	E * L1	E * L2
Sex	Y	L1	L2	P	E												
	First hatch (hatched on Dec 12, 1985)																
	Growing period																
Male	23	44	58	–	–	14	20	46	21	40	35	13	33	30	21	30	31
Female	32	29	57	235	250	14	17	27	22	38	34	15	27	35	16	28	40
	Laying period																
Pullet	24	19	48	118	120	12	12	19	21	32	26	12	21	28	16	21	34
	Second hatch (hatched on May 1, 1986)																
	Growing period																
Male	52	59	59	–	–	25	31	33	33	28	21	22	39	39	29	37	37
Female	46	77	64	208	217	45	31	45	42	44	31	24	41	31	31	43	41
	Laying period																
Pullet	39	63	40	95	96	36	24	35	28	30	24	20	36	20	28	32	28

TABLE 2. COMPOSITIONS OF EXPERIMENTAL DIETS AT DIFFERENT PERIODS

Calculated composition	Age periods (weeks of age)			
	0-6	7-14	15-19	After 20
Crude protein (%)	18.7	16.8	12.0	14.7
Metabolizable energy (kcal/kg)	2800	2800	2900	2840
Calcium (%)	.805	.705	.600	3.55
Available phosphorus (%)	.400	.350	.300	.330

weeks, 8 weeks of age and once every three months afterwards. Individual body weights were taken at hatch, 6, 12, 16, 30, 40 and 70 weeks of age. The comb size (area) of the chicken, an indication of sexual maturity, represented by the product of comb length (the linear length from the front tip to the end of the comb) and comb height (the vertical height from the base to the tip of the comb), was measured at 12 and 16 weeks of age in males and only at 16 weeks of age in females. Individual egg production records were recorded daily from 16 to 70 weeks of age. From 30 to 40 weeks of age, individual egg weights were measured for six consecutive days for every two weeks to estimate egg mass production, and feed consumption was also measured to estimate feed/egg ratio. At 25, 35, and 65 weeks of age, three eggs from each pullet were collected to measure egg qualities, such as egg shell whiteness, egg index, egg shell strength, egg shell thickness, Haugh unit, albumen weight, yolk weight and proportion of water in albumen.

Resistance to Marek's Disease

Country chickens, White Leghorns and their reciprocal crosses were also used. Strains B and S were used in trial 1 and strain L1 was used in trial 2. Strain P was used in both trials. One hundred and six and 167 chicks were used in trials 1 and 2 respectively. Marek's disease virus was prepared by Haider's method (Haider *et al.*, 1970). Every chick was injected with Marek's disease virus into the abdominal cavity at hatch. All chicks were reared in battery cages and every bird that died was taken to the Veterinary Hospital in National Chung-Hsing University for postmortem examination. Agar gel precipitation test (Ouchterlony, 1953) was conducted at 2, 4, 6, 8, 10 and 13 weeks of age in trial 1, and at 3, 5, 7 and 9 weeks of age in trial 2 to determine the accumulated rate of positive antibody response to Marek's disease virus (Mikami and Bankowski, 1971).

Antibody Titre Responses

Three trials were conducted to study the antibody titre responses to Newcastle disease (ND) virus vaccine and to sheep red blood cells (SRBC). Strains L2, P and E were used in the first two trials and strains B, S and P were used in the third trial. In trial 1, 212 pullets at 293 days of age were intramuscularly injected with 1.0 ml of inactived alumina-gel ND virus vaccine (gel-NDV) and intravenously injected with 0.1 ml 0.25% SRBC. Antibody titres responses to both antigens were measured at 0, 5, 14 and 21 days after injection. In trial 2, 249 birds were intramuscularly injected with 0.5 ml gel-NDV and 0.5 ml 20% SRBC at 32 day of age and reinforced again at 61 days of age. The antibody titres were measured at 0, 7, 14, 21 and 28 days after injection. These pullets were injected intramuscularly with 0.5 ml inactive oil-emulsion ND virus vaccine (oil-NDV) and intravenously with 0.1 ml 0.25 % SRBC at 181 days of age and the antibody titres were measured at 0, 7, 14 and 21 days after injection. In trial 3, 226 chicks were inoculated via eye with a drop of ND B1 strain virus vaccine at hatch and ND La Sota virus vaccine at 15 days of age. Antibody titres were measured at 0, 7 and 14 days after inoculation.

Analysis of Data

Since during the growing period, birds of one strain were equally divided into four groups and were housed in four blocks of two houses, the mean of the birds of a strain in one block was assumed to be the experimental unit (Y_{ij} *i.e.*, the observation of the jth strain in the ith block). Thus, it is assumed that

$$Y_{ij} = \mu + B_i + S_j + e_{ij}$$

where μ is the grand mean, B_i is the random

effect of the $_i$th block, S_j is the fixed effect of the $_j$th strain, and e_{ij} is the random error. During the laying period, the pullets of one strain are equally divided into six groups and randomly assigned to six rows of cages, the mean of pullets of one strain in one row of cages was assumed to be the experimental unit (Y_{ij}), and the statistical model is assumed to be

$$Y_{ij} = \mu + R_i + S_j + e_{ij}$$

where μ, S_j and e_{ij} are the same as those described above, and R_i is assumed to be the random effect of the $_i$th row of cages. When estimating the breed difference, the heterosis, and the reciprocal effect, strains of the same breed were given the same weight to calculate the mean of every breed. Thus, the mean of the country chicken (C) was the average of Y, L1 and L2 strains, the mean of White Leghorns (L) was the average of P and E strains, the mean of the C*L hybrid was the average of Y*P, Y*E, L1*P, L1*E, L2*P, and L2*E, and the mean of the L*C hybrid was the average of P*Y, P*L1, P*L2, E*Y, E*L1, and E*L2. The breed difference between the country chicken and White Leghorns was estimated by C − L, the heterosis was estimated by (C*L + L*C − C − L)/2, and the reciprocal effect was estimated by C*L − L*C. All these estimates were calculated by the ESTIMATE statement of the GLM procedure in the SAS computer software package (SAS, 1985). The individual bird's antibody titre was transformed into a log2 value and was used as the experimental unit for statistical analysis. The chi-square test was used to analyze the mortality of birds.

Results and Discussion

Body weights and comb sizes of birds are shown in table 3. The body weight difference between the country chicken and White Leghorns was highly significant ($P < 0.01$) at every

TABLE 3. BODY WEIGHTS AND COMB SIZES OF COUNTRY CHICKENS(C), LEGHORNS(L) AND THEIR RECIPROCAL CROSSES, AND TESTS OF BREED DIFFERENCES (C-L), HETEROSIS AND DIFFERENCES BETWEEN RECIPROCAL CROSSES

Trait	Breed mean				Breed difference		
	C	C*L	L*C	L	C-L	Hetero	C*L-L*C
Male body weight (g)							
0 wk	35	38	36	–	–	–	2**
6 wk	493	497	488		–	–	9
12 wk	1350	1274	1314	–	–	–	−40*
16 wk	2214	1993	2035	–	–	–	−42
Male comb area (cm^2)							
12 wk	1702	2574	2523	–	–	–	51
16 wk	5122	5795	6031		–	–	−237
Female body weight (g)							
0 wk	35	39	35	39	−4**	−1+	4**
6 wk	414	446	404	377	37**	30**	43**
12 wk	1050	1027	990	881	169**	43**	37**
16 wk	1721	1530	1460	1282	439**	−6	70**
30 wk	1978	1783	1746	1566	412**	−8	37+
40 wk	1996	1848	1842	1647	349**	24	7
70 wk	2157	2042	2034	1826	331**	47*	8
Female comb area (cm^2)							
16 wk	1473	1489	1272	860	613**	214**	217**

+, $P < 0.1$; *, $P < 0.05$; **, $P < 0.01$

age studied. The day-old chicks of L and C*L were 4 g heavier than those of C and L*C, which was the consequence of egg-size differences. During the growing period, the country chickens gained at a faster rate than the other breeds, but they did not gain as much weight as did the other breeds during the laying period. Heterosis of body weight was found at 6, 12 and 70 weeks of age. Females of C*L were heavier than those of L*C from hatch to 16 weeks of age, but males of C*L were lighter than those of L*C at 12 weeks of age. These data suggested that either maternal effect or sex-linked gene(s) might be very important to the body weight gain during the growing period. Comb size is an indication of sexual maturity. The data suggested that comb size was affected both by heterosis and sex-linked gene(s). The Leghorn pullets usually have larger comb size than the country pullets, and the smaller comb size of White Leghorns at 16 weeks of age might be due to later sexual maturity. This was confirmed later by the result of the age at first egg (table 4).

The country chicken's mean age at first egg was 19 days earlier than that of the White Leghorn pullet, however, it's egg was small and the production rate was very low (table 4). Even though the country chicken consumed less, the feed efficiency was very much worse than the other breeds due to the very poor egg production. Tremendous heterosis was found in almost every laying trait, *i.e.*, age at 1st egg (4.1 %), survivor's egg production from the first egg to 39 weeks of age (31.5 %), from 40 to 69 weeks of age (25.2 %), egg weights (4.5, 1.9 and 1.9 % for eggs at 25, 35

TABLE 4. PERFORMANCES OF EGG PRODUCTION OF COUNTRY CHICKENS (C), LEGHORNS (L) AND THEIR RECIPROCAL CROSSES, AND TESTS OF BREED DIFFERENCES (C – L), HETEROSIS AND DIFFERENCES BETWEEN RECIPROCAL CROSSES

Trait	Breed mean				Breed difference		
	C	C*L	L*C	L	C – L	Heterc	C*L-L*C
Age at 1st egg (day)							
	150.4	153.5	153.3	169.6	–19.1**	–6.6**	0.2
Survivor's egg production (egg)							
1st egg – 39 wk	52.4	82.5	81.7	72.5	–20.6**	19.7**	0.8
40 wk – 69 wk	65.4	121.2	123.7	130.2	–64.8**	24.7**	–2.5
1st egg – 69 wk	119.0	204.4	208.3	205.3	86.3**	44.2**	–3.9
Survivor's rate of lay (%)							
1st egg – 39 wk	40.1	65.1	64.4	65.3	25.2**	12.0**	0.7
40 wk – 69 wk	31.1	57.7	58.9	62.0	–30.9**	11.8**	–1.2
1st egg – 69 wk	34.9	60.8	61.9	64.2	–29.3**	11.8**	–1.1
Egg weight (g)							
25 wk	41.2	46.4	45.9	47.1	–5.97**	1.98**	0.54
35 wk	49.2	53.1	53.0	54.9	–5.71**	0.99**	0.06
65 wk	55.3	61.0	60.4	63.8	-8.49**	1.18**	0.61
Daily feed intake (g/pullet)							
30 – 39 wk	87.0	99.9	100.2	101.1	14.2**	6.0**	–0.3
Daily egg mass (g/pullet)							
30 39 wk	18.7	34.3	35.1	36.3	–17.6**	7.2**	–0.8
Feed efficiency (feed/egg)							
30 – 39 wk	5.18	2.95	2.95	2.81	2.37**	1.05**	0.00

**, $P < 0.01$

and 65 weeks of age, respectively), daily feed intake (6.4 %), daily egg mass (26.2 %), and feed efficiency (26.2 %). The heterosis were so large that the hybrids started to lay almost as early as the country chicken, and their egg production rate and egg size were as good as White Leghorns.

The egg shell color of the country chicken was tinted brown and was, thus, darker than that of White Leghorn (table 5). The egg shape of White Leghorn was very consistent from 25 to 65 weeks of age, but the egg of the country chicken tended to be rounder at 25 weeks of age. The egg shell strength of the country chicken was stronger than White Leghorn at every age studied. The egg shell strength of White Leghorn declined with age, but that of the country chicken was very stable. The

TABLE 5. EGG QUALITIES OF COUNTRY CHICKENS (C), LEGHORNS (L) AND THEIR RECIPROCAL CROSSES, AND TESTS OF BREED DIFFERENCES (C – L), HETEROSIS AND DIFFERENCES BETWEEN RECIPROCAL CROSSES

	Breed mean				Breed difference		
Trait	C	C*L	L*C	L	C – L	Hetero	C*L-L*C
Egg shell whiteness (W)[1]							
35 wk	73.3	83.5	84.6	90.1	16.8**	2.32**	-1.16*
65 wk	73.2	84.3	85.5	88.3	-15.1**	4.14**	-1.18**
Egg index (width/length)							
25 wk	75.2	73.5	75.3	73.6	1.57**	-0.01	-1.72**
35 wk	73.0	72.8	74.8	73.2	-0.23	0.72**	-2.03**
65 wk	73.2	71.2	73.7	73.4	0.24	-0.85*	-2.47**
Egg shell strength (kg/cm^2)							
35 wk	3.72	4.02	3.92	3.39	0.33**	0.41**	0.10
65 wk	3.68	3.29	3.21	2.83	0.85**	0.00	-0.08
Egg shell thickness (mm)							
35 wk	.374	.391	.397	.397	-.005	.017**	-.006
65 wk	.352	.352	.356	.345	.007+	.005*	-.004
Egg shell weight per unit surface area (mg/cm^2)							
35 wk	77.3	79.7	80.4	76.9	0.40	2.97**	-0.69
65 wk	76.2	75.9	76.9	74.2	1.97*	1.18*	-1.08
Haugh unit							
35 wk	84.7	88.3	88.0	92.0	-7.26**	0.22	0.31
65 wk	85.2	86.4	85.4	90.5	-5.28**	-1.92**	1.06
Albumen wt / egg wt (%)							
35 wk	60.6	61.7	61.4	63.4	-2.82**	-0.41*	0.33
65 wk	58.5	60.1	59.5	61.7	3.19**	-0.28*	0.54**
Yolk wt / egg wt (%)							
35 wk	29.7	28.4	28.6	27.2	2.47**	0.09	-0.23
65 wk	32.2	30.9	31.3	29.6	2.55**	0.22	-0.39
Albumen water (%)							
35 wk	88.1	87.4	87.3	87.7	0.35**	-0.52**	0.02
65 wk	88.2	87.8	88.2	88.1	0.13	-0.15	-0.32*

+, $P < 0.1$; *, $P < 0.05$; **, $P < 0.01$ [1] $W = 100 - \sqrt{(100 - L)^2 + (a^2 + b^2)}$

Egyptian local breeds Fayoumi and Dandarawi have also been found to have good shell strength (Amer, 1972; Valle Zarete *et al.*, 1988) which, as suggested by Horst (1988), could be caused by small egg size. In this study, little difference was found in egg shell thickness between the two breeds. The egg shell weight/egg weight ratios of the country chickens were 0.34 % and 0.63 % higher ($P < 0.01$) than those of White Leghorns at 35 and 65 weeks of age respectively. Breed difference in egg shell weight per unit surface area (Carter, 1975) was 1.97 mg/cm^2 ($P < 0.05$) at 65 weeks of age. All these data suggested that smaller egg size might be the main cause of the better egg shell quality, but differences in egg shell structure might be present and have some influence.

Since egg qualities of every egg were determined in the evening of the laying day, the Haugh units of all eggs were very high (table 5). However, the Haugh unit of the country chicken egg was significantly lower than that of the White Leghorn egg at every age measured. Rodda (1972) reported that the Haugh unit of the Rhode Island Red egg was higher than that of the White Leghorn, and Curtis *et al.* (1985) also found that the Haugh units of three commercial brown-egg breeds were higher than those of three commercial white-egg breeds. Whether or not the contrary results here were caused by the smaller egg size of the country chicken, further research is needed. Besides the better shell quality and lower Haugh unit, the country chicken also had larger yolk, and smaller albumen ratios than did the White Leghorn. Since large egg size was prefered by consumers, the egg-type chickens have been selected for egg weight for a long time. We proposed a hypothesis that the long-term selection for large egg weight with good feed efficiency might have increased the water content in albumen in the exotic breeds. However, our result did not support this hypothesis, *i.e.*, the albumen water content in the country chicken egg was not less, but even higher, than that of White Leghorn egg (table 5).

Egg shape seems to be influenced by sex-linked gene(s) as indicated by the significant difference ($P < 0.01$) in egg index between C*L and L*C. The egg of C*L was longer than that of L*C, however, the egg of the country chicken was not longer than that of the White Leghorn. One reasonable explanation is that autosomal gene(s) and sex-linked gene(s) in the country chicken have contrary effects. Further researches are needed to test this hypothesis.

Heterosis in egg shell thickness was reported by Arad and Marder (1982) when the Sinai Bedouin fowl was crossed with the White Leghorn. The egg shell of the hybrid was as thick as that of the native chicken. In our study, overdominances were found in egg shell strength, egg shell thickness and egg shell weight per unit surface area, *i.e.*, the hybrid had the best egg shell quality.

Mortalities of birds in growing and laying periods are shown in table 6. The country chicken lost many chicks during the brooding period,

TABLE 6. MORTALITIES OF DIFFERENT BREEDS IN GROWING AND LAYING PERIODS (%)

Age period	C	C*L	L*C	L
First hatch				
0- 4 week	13.2	0.0	6.3	1.0
5-16 week	1.7	0.3	1.1	1.5
17-39 week	6.5	4.1	6.8	10.1
40-69 week	0.0	0.8	1.6	7.5
Second hatch				
0- 5 week	16.0	4.2	2.2	3.5
5-16 week	21.4	6.4	16.5	15.7
17-39 week	3.4	0.0	3.0	10.4
40-69 week	3.5	2.3	0.6	4.1

which was possibly due to the poor viability of the small chick. However, the laying house mortality of the country chicken was lower than that of the White Leghorn. Significant heterosis was also found in the viability of the hybrid birds.

Genetic differences in the resistance to Marek's disease have been reported (Crittenden *et al.*, 1972; Gavora and Spencer, 1979). Comparing the country chicken with White Leghorns, no difference was found between strains B and S of the country chicken and strain P of the White Leghorn (Trial 1, table 7), but significant difference was found between strain L1 of the country chicken and strain P of the White Leghorn in trial 2. The determination of antibody in trial 2 also suggested that strain L1 had better ability to produce antibody. Heterosis in survival rate and antibody positive rate were also found in the crosses

between strains B and S of the country chicken and strain P of the White Leghorn.

Comparing it with White Leghorns, the country chicken had also been found to have higher antibody titres to Newcastle disease virus vaccine in some trials (tables 8, 9 and 10). In trial 3, the antibody titres of chicks of strains B and S in the first week were lower than strain P, which was possibly due to the maternal effect as indicated by the reciproal difference between the two hybrids. The immune response to sheep red blood cell in the country chicken was also found to be higher than that in the White Leghorn (tables 8 and 11).

During the study of laying performances, 10 White Leghorn pullets around 20 weeks of age in the first hatch and 4 White Leghorns around 7 weeks of age in the second hatch died from Leucocytozoonosis. However, no birds of the

TABLE 7. RESULTS OF CHICKS CHALLENGED WITH MAREK'S DISEASE VIRUS AT HATCH [1]

Tested items	Breed mean				Breed difference		
	C	C*L	L*C	L	C-L	Hetero	C*L-L*C
	Trial 1 (0-13 wks old)						
Survival rate (%)	18.52 (5/27)[2]	48.15 (13/27)	30.77 (8/26)	26.92 (7/26)	-8.40	16.74*	17.38
Antibody positive rate (%)	35.00 (7/20)	63.64 (14/22)	54.55 (12/22)	35.00 (7/20)	0.00	24.10*	9.09
	Trial 2 (0-9 wks old)						
Survival rate (%)	40.48 (17/42)	26.19 (11/42)	22.50 (9/40)	9.30 (4/43)	31.18**	-0.55	3.69
Antibody positive rate (%)	81.82 (27/33)	80.77 (21/26)	54.84 (17/31)	37.04 (10/27)	44.78**	8.38	25.93*

[1] Strains B and S of country chickens were used in Trial 1 and Strain L1 of country chickens was used in Trial 2. Strain P of White Leghorns was used in both trials.
[2] Numbers in parentheses are actual numbers of birds.
*, $P < 0.05$; **, $P < 0.01$

TABLE 8. ANTIBODY TITERS ($\log^2$) RESPONSES TO INTRAMUSCULAR INJECTIONS OF INACTIVATED ALUMINA-GEL NEWCASTLE DISEASE VIRUS VACCINE AND TO INTRAVENOUS INJECTIONS OF 0.1 ml 0.25 % SHEEP ERYTHROCYTES AT 293 DAYS OF AGE IN TRIAL 1 [1]

Days post inj.	Pure breeds			Crossbreeds				Breed diff.[2]	Hetero	Recip. effect
	L2	P	E	L2*P	L2*E	P*L2	E*L2			
	Response to Newcastle disease vaccine									
0	2.98	2.56	2.44	2.93	3.21	2.94	3.08	0.48	0.30	0.06
5	3.00	2.99	3.16	3.54	3.28	3.35	3.55	-0.07	0.39+	-0.04
14	4.94	4.83	4.78	4.15	4.51	4.90	4.26	0.14	-0.42	-0.25
21	4.82	4.25	3.77	4.74	4.47	4.25	4.33	0.81*	0.03	0.32
	Response to sheep erythrocytes									
0	1.13	1.04	1.12	1.14	1.14	1.00	1.06	0.05	-0.02	0.11
5	3.13	2.75	2.73	2.91	2.94	2.94	3.33	0.39*	0.10	-0.11
14	3.30	2.87	2.88	3.11	3.15	3.23	3.20	0.43*	0.09	0.09
21	1.66	1.51	1.73	1.79	1.69	1.65	1.95	0.04	0.13	-0.06

[1] L2 is a strain of country chickens, and P and E are two strains of White Leghorns.
[2] Breed diff. = C - L = L 2 - (P + E)/2
+, $P < 0.1$; *, $P < 0.05$

TABLE 9. ANTIBODY TITERS (log^2) RESPONSES TO THE INJECTIONS OF NEWCASTLE DISEASE VIRUS VACCINE IN TRIAL 2 [1]

Inj. age (d)	Type of vaccine	Days post inj.	Pure breeds			Crossbreeds				Breed diff.[2]	Hetero	Recip. effect
			L2	P	E	L2*P	L2*E	P*L2	E*L2			
			First inoculation									
32	Inact.	0	1.28	1.20	1.21	1.22	1.07	1.32	1.17	0.07	-0.05	-0.10
	aluminagel	7	2.22	2.57	2.11	2.53	1.88	2.28	1.97	-0.12	-0.12	0.08
		14	2.74	2.73	2.98	3.14	2.50	2.74	2.84	-0.12	0.01	0.03
		21	1.96	1.98	2.00	2.32	1.70	2.05	2.11	-0.06	0.07	-0.07
		28	1.61	1.60	1.62	1.91	1.50	1.64	1.80	0.00	0.10	-0.02
			Second inoculation									
61	Inact.	7	2.66	2.60	2.56	2.85	2.58	2.95	2.88	0.08	0.20+	-0.20
	aluminagel	14	4.67	4.39	4.05	4.84	4.69	4.47	4.73	0.45**	0.24**	0.17
		21	5.13	4.50	4.38	5.02	4.85	5.34	5.12	0.69**	0.30**	-0.30+
		28	5.37	5.02	4.83	5.72	5.61	5.65	5.27	0.45*	0.42**	0.21
			Third inoculation									
181	Inact.	0	2.60	2.59	2.33	2.78	2.63	2.75	2.24	0.14	0.07	0.21
	oilemul.	7	3.49	3.80	3.02	3.69	3.98	3.87	3.19	0.08	0.23	0.31
		14	6.41	6.34	5.62	6.43	5.96	6.61	5.41	0.43	0.09	0.19
		21	7.76	7.93	6.78	7.78	6.48	7.47	6.67	0.41	-0.46	0.06

[1] L2 is a strain of country chickens, and P and E are two strains of White Leghorns.
[2] Breed diff. = C - L = L2 - (P + E)/2
+, $P < 0.1$; *, $P < 0.05$; **, $P < 0.01$

TABLE 10. ANTIBODY TITERS (log^2) RESPONSES TO THE APPLICATION OF NEWCASTLE DISEASE VIRUS VACCINE IN TRIAL 3 [2]

Inj. age (d)	Type of vaccine	Days post inj.	Pure breeds			Crossbreeds				Breed diff.[2]	Hetero	Recip. effect
			B	S	P	B*P	S*P	P*B	P*S			
0	B1	0	2.04	2.23	3.00	3.47	2.97	2.20	2.14	-0.87**	0.13	1.05**
		7	1.24	1.54	2.00	2.33	2.11	1.55	1.65	-0.61**	0.22*	0.62**
		14	1.33	1.58	1.78	2.14	1.61	1.26	1.30	-0.33	-0.04	0.60**
15	Lasota	7	3.47	2.45	2.18	2.82	2.32	2.23	2.97	0.78+	0.02	-0.03
		14	2.29	2.29	1.57	1.62	1.54	1.68	1.45	0.72**	-0.36**	0.02

[1] B and S are two strains of country chickens, and P is a strain of White Leghorns.
[2] Breed diff. = C - L = (B + S)/2 - P
+, $P < 0.1$; *, $P < 0.05$; **, $P < 0.01$

other breeds had been found to die from this disease. Blood samples were collected from 371 pullets of the first hatch at 23 weeks of age and the presence of antibody to the schizont of *Leucocytozoon caulleryi* was determined by agar gel precipitation test (Ouchterlony, 1953). The antibody positive rates for the country chicken, the White Leghorn, C*L and L*C were 8/86, 49/103, 26/91 and 19/91, respectively. In recent studies in our laboratory, the direct challenge of *L. caulleryi* sporoites to different breeds of chickens also suggested that the country chicken has better resistance to Leucocytozoonosis than the White Leghorn and the commercial broiler

TABLE 11. ANTIBODY TITERS (log^2) RESPONSES TO THE INJECTIONS OF THE SHEEP ERYTHROCYTES IN TRIAL 2 [1]

Inj. age (d)	Type of antigen	Days post inj.	Pure breeds			Crossbreeds				Breed diff.[2]	Hetero	Recip. effect
			L2	P	E	L2*P	L2*E	P*L2	E*L2			
			First inoculation									
32	0.5 ml	0	0.03	0.03	0.03	0.09	0.07	0.07	0.08	0.00	0.05	0.01
	20%	7	2.68	2.74	2.68	2.90	2.85	2.59	2.50	-0.03	0.02	0.33*
	SRBC	14	2.98	2.50	2.65	2.87	2.83	2.95	3.07	0.41**	0.15	-0.16
	(intra-	21	1.88	1.75	1.96	1.68	1.56	2.00	2.11	0.03	-0.03	-0.44*
	muscle)	28	1.28	1.20	1.21	1.22	1.17	1.32	1.17	0.08	-0.02	-0.05
			Second inoculation									
61	0.05 ml	7	3.67	3.17	3.14	3.29	3.38	3.39	3.58	0.52**	-0.00	0.15
	20% SRBC	14	3.25	2.83	3.04	3.25	3.19	2.86	2.83	0.32*	-0.06	0.38
	(intra-	21	2.20	2.43	2.25	2.44	2.22	2.30	2.20	-0.14	0.02	0.08
	muscle)	28	1.09	1.09	1.00	1.22	1.00	1.11	1.00	0.05	0.02	0.06
			Third inoculation									
181	0.1 ml	0	1.38	1.30	1.31	1.40	1.27	1.32	1.20	0.08	0.05	0.08
	.25% SRBC	7	3.00	3.04	2.75	3.33	2.65	2.90	2.71	0.11	-0.05	0.19
	(intra-	14	3.22	2.88	2.92	3.29	3.12	3.00	2.79	0.32*	-0.01	0.31
	venous)	21	1.90	1.75	1.99	1.67	1.54	2.08	2.14	0.03	0.03	-0.51**

[1] L2 is a strain of country chickens, and P and E are two strains of White Leghorns.
[2] Breed diff. = C - L = L2 - (P + E)/2
+, $P < 0.1$; *, $P < 0.05$; **, $P < 0.01$

(Chen *et al.*, 1988).

The country chickens in Taiwan are favored over the exotic breeds, *i.e.*, the commercial broilers, but their production costs are high due to (1) slow growth rate, (2) elongated rearing period, (3) poor uniformity of products (as reported by Lee and Huang, 1988), and (4) poor hatching-egg production ability. The feed conversion of the country chicken during the rearing period is about 3.0. This poor feed efficiency was mainly caused by the elongated rearing period. Since the country chicken could not be sold before they show sexual maturity appearance, direct selection for the growth rate might result in a bigger chicken but still could not be accepted by the consumer. The genetic parameters of the country chicken estimated in our laboratory indicated that early sexual maturity, represented by a bigger comb size around 13 weeks of age, has a rather large heritability (h^2_S = 0.35~0.69; Huang *et al.*, 1985) and was genetically associated with better meat quality (r_G = 0.22~0.58; Lee, 1985). Thus, the first two problems might be solved by selection for early sexual maturity, and the poor uniformity might be improved by the crossbreeding production system (Lee and Huang, 1988). Tremendous heterosis in egg production traits found in this study suggests that crossing different stocks with much different genetic backgrounds to produce pullets of the parent stock might be the best solution.

The native chicken usually has better disease resistance than the exotic commercial breeds (Nordskog and Philips, 1960; Heller *et al.*, 1981), however, it has also been reported to be less viable in the intensive husbandry environment during the growing period (Horst, 1988). In our study, the country chicken had much higher mortality during the brooding period but appeared to have very good viability after that. The high mortality of chicks might be partly due to smaller chicks (table 6). Our results also suggest that the country chicken has good resistance to prevailing diseases, such as Marek's disease and Newcastle disease, and the regional disease – Leucocytozoonosis. Fan *et al.* (1986) also reported that the country

chicken had better resistance to the challenge of *Eimeria tenella* oocyst than White Leghorns. Gross *et al.* (1980) reported that the selection for high antibody titre to SRBC resulted in better resistance to virus diseases, such as Newcastle disease, and protozoan diseases, such as coccidiosis, but less resistance to bacterial infections. The country chicken in our study showed higher antibody titres to SRBC and this might well be related to their better resistances to virus diseases, *e.g.*, Marek's disease and Newcastle disease, and protozoan diseases, *e.g.*, Leucocytozoonosis and Coccidiosis.

The genetic merits of the country chicken in disease resistance and egg quality might be very useful in improving laying chickens in a warm, humid and intensive husbandry environment such as Taiwan and other southeastern Asian countries. Tremendous heterosis in egg production traits suggests that crossing the imported exotic laying breeds with the native chicken might be a good production system. The heterosis from the crossing between brown-egg and white egg birds was not a new finding. Heterosis had been reported in the cross between Rhode Island Red and White Leghorn (Wearden *et al.*, 1967) and between Australorp and White Leghorn (Sheridan and Randall, 1977). However, the large body weight and tinted egg shell color are not desirable in the developed countries. In the oriental countries, the spent hen is valuable, the large body weight might be able to cover the excess cost of feed, and the tinted egg shell is either acceptable or even preferable. Furthermore, the disease resistance merit, especially to Leucocytozoonosis, might be the best way to ensure the production of clean eggs and clean chicken meat.

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