Effects of Age and Lines on Blood Parameters in Laying Tsaiya Ducks

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ABSTRACT : Three hundred and twelve female Tsaiya ducks from four lines (L1051, L1052, L1053 and L1054) were used in this study to investigate the changes in plasma calcium and inorganic phosphorus levels, blood pH, carbon dioxide partial pressure (pCO_2), bicarbonate ion concentration ($[HCO_3^-]$), and base excess (BE) during laying periods. The results indicated that plasma calcium and inorganic phosphorus concentration at 40 and 50 wks of age were higher ($p<0.05$) than those at other ages. Significant positive correlation coefficients were found between plasma calcium and inorganic phosphorus levels at each age tested from 20 to 50 wks. Ducks from L1053 showed lower ($p<0.05$) blood pH, BE and $[HCO_3^-]$ as compared with other lines. Ducks from L1054 had higher ($p<0.05$) blood pH, BE and $[HCO_3^-]$ than those of other lines showing that there were some differences on blood parameters among lines. Eggshell strength decreased with age up to 65 wks and remained constant thereafter. Egg weight increased gradually from 30 to 60 wks and decreased slightly after 70 wks of age. Plasma inorganic phosphorus level in 40 and 50 wks old birds was positively correlated with eggshell strength, while blood $[HCO_3^-]$ in 40 and 50 wks old birds was negatively correlated with eggshell strength. ***(Asian-Aust. J. Anim. Sci. 2004. Vol 17, No. 7 : 984-989)***

Key Words : Tsaiya Duck, Blood Parameter, Age, Laying Period

INTRODUCTION

Tsaiya duck (*Anas platyrhynchos* var. *domestica*) is a primary laying duck breed in Taiwan. The traditional way of raising laying Tsaiya ducks is on the floor. Laying ducks can also be raised in cages. The egg production of ducks raised in cages is comparable to that of ducks raised on the floor, however, eggshell quality declines with age in cage feeding (Lee et al., 1991), as observed in laying hens (Izat et al., 1985). There was a significant positive correlation (r=0.77) between shell calcium and eggshell quality as assessed using deformation measurements, but a negative correlation (r=-0.50) between shell magnesium and shell quality was noted (Atteh and Leeson, 1983). The plasma calcium concentration of a chicken line laying eggs with thick shells is higher than a line laying thin eggshells (Koch et al., 1984). The plasma calcium concentration steadily decreased during egg formation from 32.0 mg/dl at 4 h postoviposition to 23.3 mg/dl at 22 h postoviposition (Van de Velde et al., 1986). In a study with ducks, it was found that, the ratio of serum calcium to inorganic phosphorus was higher in laying ducks than in nonlaying ducks (Cheng and Shen, 1985). During shell formation, there is a decrease in pH of blood in hens (Hodges, 1970). Mongin (1968) suggested that acid-base balance was an important factor influencing eggshell strength in laying hens. From this information it is clear that the data on blood parameters in ducks are not well established. The changes of blood parameters in laying ducks during egg production period must be determined. Therefore, this study was designed to investigate the changes in plasma calcium and inorganic phosphorus levels, blood pH, carbon dioxide partial pressure (pCO_2), bicarbonate ion concentration ($[HCO_3^-]$), and base excess (BE) during the laying periods of Tsaiya ducks from four different lines to establish the basic blood parameters in ducks.

MATERIALS AND METHODS

Four lines of Tsaiya ducks used in this study were the sixth generation of L1051, L1052, L1053 and L1054 maintained at the Duck Research Center of Taiwan. These ducks came from different local farms but were selected based on the same index for improving egg production and eggshell strength. The establishment of these lines has been described by Lee et al. (1992). In this study, 84 female ducks from each line were randomly selected at birth. The management of ducks during growing period was described by Lee et al. (2002). The ducks were housed in two-tier individual cages (30×33×45 cm) at 12 wks of age. A long and deep trough feeder was set in front of the cages with a nipple drinker behind every two cages. Body weight was recorded individually at 14, 20 and 40 wks of age. Light was maintained at 16 h/d after 2 wks of age. The composition diets of starter, grower and layer is shown in Table 1. Feed and water were supplied *ad libitum* throughout the experimental period except the blood sampling day. Feed was removed for 4 h before blood

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Received November 17, 2003; Accepted March 16, 2004

Table 1. Composition of experimental diets

Ingredients	Starter	Grower	Layer
	0 to 4 wk	5 to 16 wk	17 to 80 wk
	---------------------%---------------------		
Corn	57.2	52.0	50.0
Barley		20.0	
Soybean meal (44% CP)	24.0	10.0	27.5
Wheat bran	10.0	10.0	6.5
Rice hull		2.4	
Torula yeast	2.0	2.0	2.0
Fish meal	2.5		3.2
Limestone	1.0	1.0	6.0
Dicalcium phosphate	1.5	1.8	2.0
Lard	1.0		2.0
Vitamin premix[1]	0.25	0.25	0.25
Mineral premix[2]	0.2	0.2	0.2
Iodized salt	0.3	0.3	0.3
DL-methionine	0.05	0.05	0.05
Total	100.0	100.0	100.0
Calculated value:			
Crude protein, %	19.4	13.6	20.4
ME, kcal/kg	2,925	2,832	2,812
Calcium, %	0.9	0.8	3.0
Total phosphorus, %	0.8	0.7	0.8

[1] Vitamin premix supplied the followings per kilogram of diet : vitamin A, 15,000 IU; cholecalciferol, 3,000 IU; vitamin E, 25 IU; vitamin K, 6 mg; thiamin, 3 mg; riboflavin, 9 mg; pyridoxine, 6 mg; vitamin B_{12}, 0.03 mg; Ca-pantothenate, 18 mg; niacin, 60 mg; folic acid, 1.5 mg; choline-HCl, 400 mg.

[2] Mineral premix supplied the followings per kilogram of diet: Mn, 40 mg ($MnSO_4.H_2O$); Zn 60 mg (ZnO).

sampling. The egg production of each duck was recorded in the morning after the first egg was laid. Beginning at 30 wks of age, egg weight and eggshell strength were measured for 5 consecutive days in a 5 wk interval. Eggshell breaking strength was measured by compressing two ends of the egg with a load rate of 50 mm/min using a Vertical Tensile Tester (Model HT8335, Hung Ta Co., Taichung, Taiwan).

Blood samples were collected from 78 ducks from each line at 15:00 h on 3 consecutive days with 26 ducks per day at 20, 25, 30, 40 and 50 wks of age. In each duck, about 4 ml of blood was drawn from the brachial vein into a syringe containing heparin. Air was expelled and the syringe was sealed immediately with a plastic cap to prevent carbon dioxide loss. Samples were stored in ice as soon as possible. Blood pH and pCO_2 adjusted to a body temperature of 41 °C were measured within 3 h using a blood gas analyzer (Model 158, Ciba-Corning Diagnostics Corp., Medfield, MA), BE and $[HCO_3^-]$ were calculated from the two measured values at the same time (Ciba-Corning, 1988). After measurement, blood samples were centrifuged 1,000×g for 10 min, and plasma samples were taken and frozen at -21°C until analysis. Plasma calcium was measured by diluting 0.1 ml plasma to 10 ml with 0.1% La_2O_3 solution using an Atomic Absorption Spectrophotometer (Model 3100, Perkin Elmer Corp., Norwalk, CT). Plasma inorganic phosphorus was measured by spectrophotometer (Model DU-60, Beckman Instruments Inc., Fullerton, CA) following the method of Chen et al. (1956).

Table 2. Egg production performance of Tsaiya ducks from age of first egg (AFE) to 52 wk of age in 4 lines

Lines	AFE (day)	Egg production	Body weight (kg)		
			14 wk	20 wk	40 wk
L1051	109[ab]	90.2	1.20[b]	1.35[b]	1.36[b]
L1052	112[ab]	90.3	1.20[b]	1.33[b]	1.36[b]
L1053	113[a]	89.5	1.18[b]	1.34[b]	1.39[ab]
L1054	108[b]	91.3	1.25[a]	1.41[a]	1.41[a]
Pooled SE	1	0.9	0.01	0.01	0.01

[a, b] Means within the same column without common superscripts differ significantly ($p<0.05$).

Blood parameter data were subjected to mixed model analysis using the MIXED procedure of SAS® (SAS, 1996). The model included line, age and the interaction of line with age as fixed effects and declared the sampling day as a random effect. The contrast statement in the MIXED procedure separated mean differences. The blood parameter data from ducks without eggs in the oviduct at sampling time were discarded. Mean differences of egg weight and eggshell strength were separated using the probability of difference option of least squares mean statement in the General Linear Models (GLM) procedure. GLM procedure and Tukey's honest significant difference test were used to compare the line differences of body weight, age of first egg and egg production rate. Differences were considered to be significant at $p<0.05$.

RESULTS AND DISCUSSION

The performance of the Tsaiya ducks used in this study is shown in Table 2. There were no significant differences in egg production rate among 4 lines (L1051, L1052, L1053 and L1054). Ducks from L1054 showed higher body weight than those in other lines. Ducks from L1054 showed early sexual maturity than those in L1053. Studying on 1st to 4th generation performance of Tsaiya ducks, Lee et al. (1992) indicated that ducks from L1054 showed higher body weight at 40 wks of age than those in other lines. Ducks from L1053 showed later sexual maturity than those in L1052 and L1054 from 1st to 3rd generation. Ducks from L1053 showed higher egg production rate than those in L1054 from 2nd to 4th generation. Ducks from L1054 also showed higher body weight and early sexual maturity than those in other lines in 6th generation. However, there was no difference in egg production rate among 4 lines in this study. This means that ducks would tend to exhibit similar performance based on the same selection index.

The effects of age and line on plasma calcium and

Table 3. Effects of age and lines on plasma calcium and inorganic phosphorus levels in laying Tsaiya ducks[1]

Age of week (n)[2]	Lines of ducks				Means	SE
	L1051	L1052	L1053	L1054		
			Plasma calcium (mg/dl)			
20 (269)	32.34	33.32	29.64	30.54	31.50[z]	0.84
25 (277)	33.99	36.10	32.10	32.37	33.67[y]	0.84
30 (273)	32.28	31.80	30.76	28.89	31.02[z]	0.84
40 (271)	36.86	36.74	36.71	36.86	36.85[x]	0.84
50 (269)	37.47	35.92	35.39	35.33	36.09[x]	0.85
Means	34.61[a]	34.86[a]	32.98[b]	32.86[b]		
SE	0.84	0.82	0.82	0.81		
			Plasma inorganic phosphorus (mg/dl)			
20 (269)	14.46	15.61	13.45	13.63	14.33[z]	0.84
25 (277)	15.04	15.51	14.36	14.43	14.87[yz]	0.84
30 (273)	14.74	14.82	14.71	14.18	14.70[z]	0.84
40 (271)	16.75	17.03	17.53	16.94	17.11[x]	0.84
50 (269)	16.08	15.39	14.78	15.16	15.42[y]	0.84
Means	15.42[ab]	15.75[a]	15.03[b]	14.94[b]		
SE	0.84	0.83	0.83	0.83		

[a, b] Least squares means in a row without common superscripts differ significantly ($p<0.05$).
[x-z] Least squares means in a column without common superscripts differ significantly ($p<0.05$).
[1] No significant interactions of age by lines. [2] Valid sample size.

inorganic phosphorus levels in laying Tsaiya ducks are shown in Table 3. The combined plasma calcium concentration for ducks from 4 lines was highest at 40 and 50 wks of age and lowest at 20 and 30 wks of age. Ducks from L1051 and L1052 had higher overall plasma calcium levels than others. Among all ages, plasma inorganic phosphorus level at 40 wks of age was the highest and the lowest was at 20 and 30 wks of age. Ducks from L1052 showed higher plasma inorganic phosphorus level than those in L1053 and L1054. Significant positive correlation coefficients (0.55 to 0.65) were found between plasma calcium and inorganic phosphorus levels at each age tested from 20 to 50 wks. Similar results were reported by Wideman and Buss (1985) with Leghorn hens. This high positive correlation may be due to close coordination of these two variables in the metabolism. The plasma calcium level of ducks during the laying period in this study was similar to the results of Cheng and Shen (1985), but was higher than the results of Parsons and Combs (1981) with 18 month old Leghorn hens. Chen and Shen (1989) also reported that the ducks retained more calcium from feed than Leghorn hens, and the calcium content in the duck eggshells was significantly higher than those of hens. As for inorganic phosphorus level, Wideman and Buss (1985) indicated that the range of plasma inorganic phosphorus from blood collected between 2.5 and 4.0 h postoviposition at 35 wks of age in different lines of laying hens was 5.8 to 7.6 mg/dl. Our results were higher than those obtained by Wideman and Buss (1985). This might be due to differences in blood collection time and species. In a study on Khaki Campbell ducks, Simmons and Hetzel (1983) indicated that the ovum spent 15 to 30 min in the infundibulum, 2.5 to 3 h in the magnum, 2 to 2.5 h in the isthmus and 18.6 h in the shell gland with overall less egg formation time than laying hens. The oviposition time of Tsaiya ducks was known to be between 23:00 and 05:00 (Lee et al., 1990), so blood samples in this study were collected at about 15:00 in which eggshell formation was in progress. Mongin and Sauveur (1979) reported that the plasma phosphorus of Leghorn hens varied from 2.5 mg/dl at 10 h postoviposition to 4.2 mg/dl at 22 h postoviposition. Cheng and Shen (1985) indicated that serum inorganic phosphorus of Tsaiya ducks was lowest (5.55 mg/dl) at 3 h postoviposition, and highest (10.02 mg/dl) at 15 h postoviposition. Calcium and phosphorus content in bone ash of laying hens were 37 and 17%, respectively, and were 38 and 0.08%, respectively, in eggshell ash (Atteh and Leeson, 1983). Because of higher content of phosphorus in bone than in eggshell, the release of calcium and phosphorus salts from bone might result in a higher inorganic phosphorus level in the plasma.

The effects of age and line on blood pH and base excess (BE) in laying Tsaiya ducks are shown in Table 4. Blood pH was at the highest level at 30 wks of age and at the lowest level at 50 wks of age. Among 4 lines, blood pH was highest in L1054 ducks and lowest in L1052 and L1053 ducks. Blood BE was highest at 30 wks of age and lowest at 20, 25 and 40 wks of age. Similar to blood pH, blood BE was highest in L1054 ducks and lowest in L1052 and L1053 ducks. Blood pCO_2 was at the highest level at 50 wks of age and at the lowest level at 20 and 25 wks of age (Table 5). Ducks from L1052 showed higher blood pCO_2 than those in L1051 and L1054. Blood $[HCO_3^-]$ at 30 and 50 wks of age was higher than those at other ages (Table 5). Among 4 lines, blood $[HCO_3^-]$ was highest in L1054 ducks and lowest in L1053 ducks. L1053 ducks showed lower blood BE and $[HCO_3^-]$ as compared with other lines. Lee et

Table 4. Effects of age and lines on blood pH and base excess in laying Tsaiya ducks[1]

Age of week (n)[2]	Lines of ducks				Means	SE
	L1051	L1052	L1053	L1054		
			pH			
20 (269)	7.278	7.259	7.256	7.275	7.267^{y}	0.004
25 (277)	7.273	7.264	7.262	7.281	7.270^{y}	0.004
30 (273)	7.292	7.282	7.277	7.306	7.289^{x}	0.004
40 (271)	7.270	7.249	7.247	7.283	7.262^{yz}	0.004
50 (269)	7.263	7.240	7.241	7.273	7.254^{z}	0.004
Means	7.275^{b}	7.259^{c}	7.257^{c}	7.284^{a}		
SE	0.004	0.004	0.004	0.003		
			Base excess			
20 (269)	-1.5	-2.6	-3.1	-1.2	-2.1^{z}	0.2
25 (277)	-1.9	-1.9	-2.6	-1.3	-1.9^{z}	0.2
30 (273)	-0.1	-0.5	-1.1	0.8	-0.2^{x}	0.2
40 (271)	-1.6	-2.4	-2.8	-0.8	-1.9^{z}	0.1
50 (269)	-0.8	-1.8	-2.0	-0.2	-1.2^{y}	0.2
Means	-1.2^{b}	-1.8^{c}	-2.3^{d}	-0.6^{a}		
SE	0.2	0.1	0.1	0.1		

[a-d] Least squares means in a row without common superscripts differ significantly (p<0.05).
[x-z] Least squares means in a column without common superscripts differ significantly (p<0.05).
[1] No significant interactions of age by lines. [2] Valid sample size.

Table 5. Effects of age and lines on blood pCO_2 and $[HCO_3^-]$ in laying Tsaiya ducks[1]

Age of week (n)[2]	Lines of ducks				Means	SE
	L1051	L1052	L1053	L1054		
			pCO_2 (mmHg)			
20 (269)	53.9	54.6	53.8	55.0	54.3^{z}	0.8
25 (277)	53.9	55.7	54.1	53.9	54.4^{z}	0.8
30 (273)	54.9	56.0	55.4	54.4	55.2^{yz}	0.8
40 (271)	55.3	57.7	56.6	54.7	56.1^{y}	0.8
50 (269)	59.5	61.3	60.6	58.9	60.1^{x}	0.8
Means	55.5^{b}	57.0^{a}	56.1^{ab}	55.4^{b}		
SE	0.8	0.8	0.8	0.8		
			$[HCO_3^-]$ (mmol/l)			
20 (269)	24.2	23.5	22.9	24.6	23.8^{y}	0.2
25 (277)	23.9	24.2	23.4	24.3	23.9^{y}	0.2
30 (273)	25.5	25.4	24.7	26.1	25.4^{x}	0.2
40 (271)	24.4	24.1	23.6	24.9	24.2^{y}	0.2
50 (269)	25.7	25.1	24.8	26.1	25.4^{x}	0.2
Means	24.7^{b}	24.4^{b}	23.9^{c}	25.2^{a}		
SE	0.2	0.2	0.2	0.2		

[a-c] Least squares means in a row without common superscripts differ significantly (p<0.05).
[x-z] Least squares means in a column without common superscripts differ significantly (p<0.05).
[1] No significant interactions of age by lines. [2] Valid sample size.

al. (2002) indicated that ducks of L1054 had heaviest body weight and earlier age of first egg accompanying with highest blood pH, BE and $[HCO_3^-]$ among 4 lines in growing period. The similar phenomenon was observed in laying period showing that there were some differences on blood parameters among 4 lines. This study showed lower blood pH and higher blood pCO_2 than the results of Balnave et al. (1989) in Leghorn hens at 2 h before oviposition, which might also be due to differences in blood collection time and species. Lee et al. (2002) indicated that age significantly affected all of these blood parameters in growing period of Tsaiya ducks. Blood $[HCO_3^-]$ steadily increased from 20.9 mmol/l at 5 wks of age to 24.8 mmol/l at 14 wks of age and blood pCO_2 changed from 38.5 mmHg at 11 wks of age to 54.8 mmHg at 14 wks of age. The change in blood parameters during the growing period may be due to the sexual maturity and estrogen secretion. The blood parameters were stable in the laying period compared with the growing period in Tsaiya ducks.

The eggshell strength gradually decreased with age and the egg weight increased up to 70 wks of age (Table 6). The eggshell strength decreased from 3.98 kg at 30 wks to 2.69 kg at 65 wks of age, and then stabilized. Egg weight increased about 6.1 g from 30 to 60 wks of age, and then

Table 6. Effects of age and lines on eggshell strength and egg weight of Tsaiya ducks[1]

Age of week (n)[2]	Lines of ducks				Means	SE
	L1051	L1052	L1053	L1054		
			Eggshell strength (kg)			
30 (300)	4.08	3.96	3.99	3.89	3.98[v]	0.04
35 (299)	3.86	3.79	3.89	3.72	3.81[w]	0.04
40 (300)	3.74	3.75	3.77	3.68	3.73[w]	0.04
45 (298)	3.63	3.56	3.59	3.57	3.59[x]	0.04
50 (299)	3.60	3.51	3.62	3.53	3.56[x]	0.04
55 (290)	3.25	3.24	3.20	3.22	3.23[y]	0.04
60 (286)	3.16	3.04	3.17	3.05	3.11[y]	0.04
65 (280)	2.76	2.66	2.62	2.72	2.69[z]	0.04
70 (271)	2.83	2.72	2.71	2.73	2.75[z]	0.04
75 (240)	2.78	2.60	2.63	2.67	2.67[z]	0.04
80 (237)	2.65	2.54	2.58	2.64	2.60[z]	0.04
Means	3.30[a]	3.21[a]	3.25[a]	3.22[a]		
SE	0.03	0.03	0.03	0.02		
			Egg weight (g)			
30 (300)	62.4	61.8	62.7	61.9	62.2[z]	0.3
35 (299)	65.6	64.9	66.2	65.4	65.5[y]	0.3
40 (300)	67.0	65.7	67.5	66.7	66.7[w]	0.3
45 (298)	66.1	64.4	66.4	66.0	65.7[xy]	0.3
50 (299)	66.6	64.8	65.8	66.0	65.8[xy]	0.3
55 (290)	67.2	65.0	66.9	66.8	66.5[wx]	0.3
60 (286)	68.8	66.8	69.0	68.5	68.3[v]	0.3
65 (280)	68.0	66.0	66.9	67.1	67.0[w]	0.3
70 (271)	68.1	67.3	68.8	67.9	68.0[v]	0.3
75 (240)	67.4	65.2	66.3	66.4	66.3[wx]	0.3
80 (237)	66.5	64.5	65.6	65.4	65.5[y]	0.3
Means	66.7[a]	65.1[c]	66.5[ab]	66.2[b]		
SE	0.2	0.2	0.2	0.1		

[a-c] Least squares means in a row without common superscripts differ significantly ($p<0.05$).
[v-z] Least squares means in a column without common superscripts differ significantly ($p<0.05$).
[1] No significant interactions of age by lines. [2] Valid sample size.

Table 7. Correlation coefficients of eggshell strength between 50 weeks and other ages of pooled 4 lines of laying Tsaiya ducks

Age (wks)	Correlation coefficient	Age (wks)	Correlation coefficient
30	0.54**	60	0.70**
35	0.61**	65	0.64**
40	0.69**	70	0.58**
45	0.80**	75	0.55**
55	0.75**	80	0.54**

** $p<0.01$.

decreased slightly after 70 wks of age. No significant interactions between line and age were found for egg weight, and eggshell strength. There was no difference for eggshell strength and egg production among 4 lines, while L1052 birds produced lighter eggs than the other lines. Roland (1979) found that eggshell quality declined as a hen aged. This might be due to the continuous increase in egg size. Izat et al. (1985) indicated that shell weight increased with increasing age in laying hens whereas the percentage of shell in an egg decreased. In this study, the decrease in eggshell strength before 65 wks might be due to an increase in egg weight. According to the time profile analysis, there was a significant ($p<0.01$) quadratic effect between egg weight and age, while a significant ($p<0.01$) linear effect was obtained between eggshell strength and age. As shown in Table 6, eggshell strength decreased by 0.03 kg per week in a type of linear regression. Eggshell strength decreased by 34.7% while egg weight increased by 5.3% between 30 and 80 wks of age.

Eggshell strength of 50 wks of age was one of the selection traits. The correlation coefficients for eggshell strength between 50 wks old and other ages for 4 lines were found to be significant as shown in Table 7. This means that eggshell strength at 50 wks of age is able to represent the eggshell strength for the duck during a laying period from 30 to 80 wks of age. Correlation coefficients between eggshell strength and the various blood traits were determined in this study (Table 8). There was a significant negative correlation between blood [HCO_3^-] and eggshell strength at 40 ($r=-0.14$) and 50 ($r=-0.15$) wks of age. A significant positive correlation coefficient was found between plasma inorganic phosphorus and eggshell strength at 40 ($r=0.15$) and 50 ($r=0.18$) wks of age. In a study on Leghorn hens, Paul and Snetsinger (1969) found a low

Table 8. Correlation coefficients between eggshell strength and blood traits at same age of pooled 4 lines of laying Tsaiya ducks

Age (wks)	Ca	P	pH	BE	pCO_2	$[HCO_3^-]$
30	-0.01	0.03	0.01	0.01	-0.01	0.01
40	0.07	0.15*	-0.05	-0.12	-0.03	-0.14*
50	-0.01	0.18*	-0.04	-0.13	-0.05	-0.15*

* $p<0.05$.

correlation between shell breaking strength and plasma calcium content or plasma inorganic phosphorus level. While Hamilton and Thompson (1980) found a weak relationship between the blood acid-base variables and shell quality in laying hens. The correlation between eggshell strength and blood $[HCO_3^-]$ or plasma inorganic phosphorus found in this study, which might be practicable for eggshell strength improvement in ducks raised in cages.

Though, ducks would tend to show similar performance on selection traits based on the same selection index, ducks from L1053 showed lower blood BE and $[HCO_3^-]$ compared with the other lines. Ducks from L1054 had higher blood pH, BE and $[HCO_3^-]$ than those from other lines. Because of the stable diurnal rhythm during the laying period, the age effect was slight on blood parameters compared with the growing period of Tsaiya ducks.

ACKNOWLEGMENT

Thanks are due to the National Science Council for providing the research grant under the project NSC-83-0409-B002-013.

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