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Intra-Clutch Changes in Egg Composition and Shell Quality in Laying Hens

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Intra-clutch changes in egg composition and shell quality were examined using two laying hen strains (High line : 40 hens, Low line : 39 hens) which were developed by a divergent selection for yolk-albumen ratio. Oviposition time was recorded every 30 minutes from 5 : 30 to 18 : 30 for a duration of 90 days at about 270 days of age. The eggs of individual hens were collected every day from three consecutive clutches. Only the hens that formed the clutches determined apparently by their oviposition time were used for the analyses. Statistical analyses were performed separately for the four clutch size groups.

The lag in oviposition time was the longest for the last egg of the clutch (terminal egg). There was no difference in the oviposition interval between lines. The changes in egg weight of consecutive eggs within a clutch showed that the first egg of the clutch was the heaviest and then the weight gradually decreased. The decrease in weight the low line was estimated to be 3.0-4.0 g, or 6% of the 1st egg, while the decrease in weight in the high line was 1.5-2.0 g (4% of the first egg). The yolk weight of the 2nd egg was heavier than that of other eggs in the same clutch, and decreased by 1.0-1.5 g in both lines. Albumen weight showed a remarkable decrease from the first egg to the 3rd or the 4th eggs of the clutch, then the decrease tended to be smaller. The decrease in the low line, which had a larger amount of albumen, was estimated to be larger. Thick albumen weight tended to decrease as the serial number within a clutch increased. However, thin albumen weight increased slightly in eggs laid at later positions of the clutch. Egg-shell weight, thickness and strength showed a clear increase in the terminal egg of the clutch.

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Key words : egg composition, shell quality, clutch position, laying hen

Introduction

The supply in the present egg production industry is stable as a result of intensive selection for the number of eggs or rate of lay. HUNTON (1984) reported on the selection limit of egg production efficiency and pointed out that egg laying efficiency has approached a physiological limit. However, even though the number of eggs produced from commercial hens is almost the same, the size and composition of the eggs are not always the same. MIYOSHI and MITSUMOTO (1994) reported that there are great variations in egg composition among laying flocks. Egg weights were also reported to change greatly with the age of the hen (HURNIK *et al.*, 1977 ; FLETCHER *et al.*, 1981 ;

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MIYOSHI *et al.*, 1996 a). There have also been several reports about the relationship of oviposition time to egg weight and egg-shell quality (ROLAND *et al.*, 1975 ; ROLAND and HARMS, 1974 ; WASHBURN and POTLS, 1975). However, most of these reports to compared the character of eggs laid in the morning and in the afternoon. CHOI *et al.*(1981) investigated the relationship between oviposition time and egg weight, and showed that the average weight of eggs laid in the morning was heavier than that of eggs laid in the afternoon, because most of the first eggs in clutches were laid in the morning. HASHIGUCHI (1996) also reported that the shell thickness and shell strength of the last eggs in the clutch were superior to those of the other eggs. LILLPER and WILHELMSON (1993) reported that egg weight decreased significantly as the serial number within a clutch increased, but there were no significant changes in egg weight for clutch sizes of more than 18 eggs. In the present study, we investigated changes in egg weight, egg component weights and egg-shell quality within a clutch in two lines that produced significant differences in egg composition.

Materials and Methods

A total of 79 hens (40 high line and 39 low line) was used in this study. The hens were from the 24th generation of a White Leghorn population, which was founded by a divergent selection for high and low yolk-albumen ratios for 12 generations from 1970. The selection was relaxed from the 13th generation (MIYOSHI *et al.* ; 1996 b). To determine the positions of the eggs laid in a clutch (clutch position), oviposition time was recorded every 30 minutes from 5 : 30 AM to 6 : 30 PM for 90 days from 270 days of age. The hens were reared in single cages in a windowless house with 12 hours of light from 6 : 00 AM to 6 : 00 PM. Feed was supplied *ad libitum*. The eggs from three distinct clutches of each hen were collected after a 30-day period of observing oviposition time. The eggs were collected every day and stored overnight at 4℃ for measuring egg traits on the next day. After weighing, the egg-shell strength of each egg was measured with an egg-shell strength meter that was pressed on the vertical axis of the egg until the egg broke. The yolk and albumen were separated. The yolk weight and shell weight (including egg-shell membrane) were measured after removing as much of the adherent albumen as possible. The albumen was separated into thick and thin albumen portions by using metallic meshes with a 2-mm lattice, and the weight of each portion was measured. The albumen weight was calculated as the sum of thick and thin albumen weights. The egg-shell thickness (excluding the membrane) was calculated as the average of three values measured at three points on the equator of the egg by a dial pipe gauge. Measurement values from the hens that had distinguishable clutches were used and were divided into four groups of different clutch sizes. These groups included 3-egg, 4~6-egg, 7~9-egg and 10~19-egg clutch sizes. The first three eggs in groups 1 and 2, the first six and nine eggs in groups 3 and 4 respectively, and the last eggs of the clutches (terminal eggs) in all the groups were used for the analyses. These designations are shown in Table 1. Statistical analyses were performed using SAS (SAS institute Inc. ; 1985). The test of significance of the means was done by DUNCAN's multiple range test.

Table 1. Number of eggs used in each clutch position

	G	No. of hen	Clutch position 1	2	3	4	5	6	7	8	9	T
High line	1	4	12	12								12
	2	15	43	42	42							44
	3	7	20	19	19	17	20	18				20
	4	3	9	9	9	9	8	8	9	6	9	9
Low line	1	5	13	14								15
	2	15	44	44	42							45
	3	7	20	20	20	19	19	19				20
	4	7	20	17	19	17	17	20	18	20	18	20

G : Clutch size group (1 : 3 eggs, 2 : 4~6 eggs, 3 : 7~9 eggs, and 4 : 10~19 eggs),
T : Terminal eggs (the last egg of the clutch).
High line and low line refer to hens selected for high and low yolk-albumen ratios.

Results

Means and standard deviations of oviposition time and its lag (LAG) at the different positions within a clutch for the high and low lines are shown in Table 2. The 1st eggs in the clutch sizes of 3 eggs were laid at 7 : 35 and 7 : 51 AM, respectively for the high and low lines. These first eggs tended to be laid earlier for the longer clutches in both the high and low lines. Thus, in the clutch sizes of 10~19 eggs, the first eggs of the clutches were laid at 6 : 34 and 6 : 30 AM for the high and low lines, respectively. The LAG values of the second and third eggs in the clutch sizes of 3 eggs were 2.67 and 3.63 hours in the high line and 2.15 and 4.12 hours in the low line. Most terminal eggs were laid in the afternoon after 2 : 00 PM and had the longest LAG values, especially for the large clutch sizes. For example, in group 2 the LAG values were 1.34~1.72 hours for the high line and 1.50~1.89 hours for the low line for the eggs in the second and third positions, while the LAG values of the terminal eggs in the same clutch size group were 4.17 and 4.73 hours for the high and low lines, respectively. The same trend was also observed for groups 3 and 4 in both lines.

Intra-clutch changes in egg weight, yolk weight and albumen weight are shown in Table 3. Egg weights of the 1st eggs of the clutches were the heaviest and then tended to decrease for subsequent eggs in all the clutch size groups of both lines. A large difference in egg weight between the 1st egg and subsequent eggs (3-4 g or about 6%) was observed. The high line egg weight was significantly lighter, and the decrease in egg weight for subsequent eggs compared to the 1st egg was also less (1.5-2.0 g). Yolk weight of the 2nd eggs in the clutches tended to be heavier than other eggs in the same clutch, and the yolk weight decreased after the 2nd egg. The terminal eggs of the clutches were lighter than the 1st and 2nd eggs by 1.0-1.5 g in both lines. Albumen weight of the 1st eggs was the heaviest and then decreased with increases in the serial number within a clutch. However, the decrease tended to be stagnant at the 3rd egg in the high line and at the 4th egg in the low line.

The changes in thick and thin albumen weights are presented in Table 4. The

Table 2. Means (time) ± SD (hour) of oviposition time and LAG (hour) for each clutch position

		High line		Low line	
G	P	Oviposition time	LAG	Oviposition time	LAG
1	1	7:35±0.97		7:51±1.03	
	2	10:15±0.66	2.67	10:00±1.11	2.15
	T	13:53±0.83	3.63	14:07±1.29	4.12
2	1	7:25±1.09		6:56±0.62	
	2	9:08±0.95	1.72	8:49±0.67	1.89
	3	10:29±1.23	1.34	10:19±1.04	1.50
	T	14:39±1.03	4.17	15:03±0.96	4.73
3	1	7:06±1.05		6:30±0.65	
	2	8:32±0.98	1.43	8:06±0.53	1.60
	3	9:25±1.61	0.89	9:05±0.61	0.98
	4	9:41±0.79	0.26	9:25±0.51	0.34
	5	10:12±1.19	0.52	9:53±0.83	0.47
	6	11:05±1.22	0.88	10:55±1.13	1.03
	T	14:50±1.00	3.75	14:53±0.89	3.96
4	1	6:34±0.77		6:30±0.90	
	2	7:26±0.73	0.88	7:34±0.75	1.06
	3	8:13±0.79	0.78	8:20±0.80	0.78
	4	8:50±0.75	0.61	8:28±0.80	0.13
	5	9:00±0.53	0.17	8:44±0.92	0.27
	6	9:15±0.93	0.25	9:00±0.97	0.26
	7	9:17±0.91	0.03	9:17±1.15	0.28
	8	9:25±0.58	0.14	9:48±1.02	0.52
	9	10:07±0.96	0.69	10:25±1.36	0.62
	T	15:00±1.00	4.89	14:08±1.47	3.71

G : Clutch size group (see Table 1), P : Clutch position,
T : Terminal egg (the last egg of the clutch),
LAG : Oviposition interval minus 24 hr.
High line and Low line refer to hens selected for high and low yolk-albumen ratios.

thick albumen weights were the heaviest in the 1st eggs and decreased in eggs laid later in the same clutch. The decrease in the low line, which had a greater thick albumen weight, was larger than that in the high line. For example, in clutch size group 3, thick albumen weights of the first eggs were 13.8 and 15.0 grams for the high and low lines, respectively. The corresponding values of the terminal eggs were 12.4 and 13.0 grams. On the other hand, thin albumen weight showed a small decrease in the first two or three eggs in clutches and then slightly increased in the eggs laid later in the same clutch. Thin albumen weights were significantly heavier in the low line than in the high line for all the positions.

Table 5 shows intra-clutch changes in egg-shell weight, egg-shell strength and egg-shell thickness. Shell weights were heavier for the 1st eggs and terminal eggs in the clutches than those for the interrupted eggs in the same clutch. The terminal eggs

Table 3. Means ± SD of egg weight, yolk weight and albumen weight

		Egg weight (g)			Yolk weight (g)			Albumen weight (g)		
G	P	High line		Low line	High line		Low line	High line		Low line
1	1	51.3 ± 3.4^{a}	*	54.8 ± 3.7^{a}	16.2 ± 1.6^{a}		15.9 ± 1.6^{a}	29.9 ± 1.8^{a}	**	33.4 ± 2.1^{a}
	2	50.9 ± 3.5^{a}		51.9 ± 3.3^{b}	16.2 ± 1.7^{a}		15.3 ± 1.5^{a}	29.5 ± 1.9^{a}	*	31.1 ± 2.0^{b}
	T	49.9 ± 3.2^{a}		51.6 ± 4.3^{b}	15.5 ± 1.7^{a}		15.0 ± 1.7^{a}	29.2 ± 1.5^{a}	*	30.9 ± 2.5^{b}
2	1	51.1 ± 2.5^{a}	**	55.1 ± 4.1^{a}	16.1 ± 1.3^{a}	**	15.2 ± 1.3^{a}	29.8 ± 1.6^{a}	**	34.3 ± 3.2^{a}
	2	50.5 ± 2.6^{ab}	**	54.5 ± 4.9^{ab}	16.2 ± 1.2^{a}	**	15.3 ± 1.5^{a}	29.1 ± 1.8^{ab}	**	33.4 ± 3.6^{ab}
	3	49.7 ± 2.8^{b}	**	53.5 ± 4.4^{ab}	15.9 ± 1.3^{ab}	**	15.0 ± 1.4^{ab}	28.7 ± 1.8^{b}	**	32.9 ± 3.1^{ab}
	T	49.4 ± 2.8^{b}	**	52.6 ± 4.6^{b}	15.4 ± 1.3^{b}	**	14.5 ± 1.5^{b}	28.6 ± 1.8^{b}	**	32.3 ± 3.3^{b}
3	1	51.7 ± 2.9^{a}	**	55.4 ± 5.3^{a}	16.2 ± 1.3^{a}	**	15.0 ± 1.1^{ab}	30.0 ± 1.4^{a}	**	34.8 ± 4.6^{a}
	2	51.1 ± 3.1^{ab}	**	54.6 ± 4.7^{ab}	16.2 ± 1.2^{a}	**	15.1 ± 1.0^{a}	29.5 ± 1.7^{ab}	**	33.8 ± 3.8^{ab}
	3	49.8 ± 3.3^{ab}	**	53.8 ± 4.7^{ab}	16.0 ± 1.5^{ab}	*	15.0 ± 0.8^{ab}	28.6 ± 1.7^{b}	**	33.2 ± 3.8^{ab}
	4	50.6 ± 2.5^{ab}		52.1 ± 4.9^{ab}	16.0 ± 1.2^{ab}	**	14.6 ± 1.0^{abc}	29.3 ± 1.4^{ab}	**	32.2 ± 3.8^{ab}
	5	49.9 ± 3.0^{ab}	*	52.5 ± 4.5^{ab}	15.6 ± 1.2^{ab}	*	14.7 ± 1.3^{abc}	29.0 ± 1.8^{ab}	**	32.4 ± 3.5^{ab}
	6	49.7 ± 3.1^{ab}		51.6 ± 4.5^{b}	15.6 ± 1.3^{ab}	**	14.4 ± 0.9^{bc}	28.9 ± 1.6^{ab}	**	31.8 ± 3.6^{b}
	T	49.0 ± 3.3^{b}	*	52.1 ± 5.8^{ab}	15.2 ± 1.3^{b}	**	14.0 ± 1.2^{c}	$28:3\pm1.8^{b}$	**	32.3 ± 4.6^{ab}
4	1	51.3 ± 1.8^{a}	**	58.2 ± 4.9^{a}	16.5 ± 0.8^{ab}		16.5 ± 0.8^{ab}	29.6 ± 1.3^{a}	**	36.7 ± 4.0^{a}
	2	51.1 ± 3.2^{a}	*	56.8 ± 5.8^{ab}	16.7 ± 1.1^{a}	*	15.6 ± 1.3^{a}	29.2 ± 2.2^{a}	**	35.3 ± 4.8^{ab}
	3	50.3 ± 2.4^{a}	**	56.0 ± 5.2^{ab}	16.5 ± 0.7^{ab}	*	15.6 ± 1.0^{a}	28.6 ± 1.7^{a}	**	34.8 ± 4.2^{ab}
	4	50.4 ± 2.8^{a}	**	55.0 ± 4.4^{ab}	16.6 ± 0.7^{ab}	*	15.5 ± 1.1^{a}	28.6 ± 1.9^{a}	**	33.8 ± 3.4^{b}
	5	50.4 ± 2.5^{a}	*	54.6 ± 4.4^{b}	16.4 ± 0.7^{ab}	*	15.4 ± 1.1^{ab}	28.8 ± 1.7^{a}	**	33.5 ± 3.3^{b}
	6	50.6 ± 2.9^{a}	*	55.1 ± 4.6^{ab}	16.5 ± 1.0^{ab}	**	15.1 ± 1.0^{ab}	29.0 ± 1.8^{a}	**	34.4 ± 3.7^{ab}
	7	50.3 ± 2.5^{a}	*	54.6 ± 4.6^{b}	16.7 ± 1.1^{a}	**	14.9 ± 1.2^{abc}	28.5 ± 1.7^{a}	**	34.1 ± 3.7^{ab}
	8	50.1 ± 2.9^{a}	*	55.3 ± 5.3^{ab}	16.6 ± 1.4^{ab}	**	15.0 ± 1.0^{ab}	28.5 ± 1.6^{a}	**	34.7 ± 4.2^{ab}
	9	49.7 ± 3.0^{a}	*	53.8 ± 4.3^{b}	16.2 ± 1.2^{ab}	**	14.7 ± 0.9^{bc}	28.6 ± 1.9^{a}	**	33.6 ± 3.4^{b}
	T	49.2 ± 3.3^{a}	*	53.4 ± 4.4^{b}	15.6 ± 0.8^{b}	**	14.2 ± 1.0^{c}	28.3 ± 2.3^{a}	**	33.3 ± 3.4^{b}

G : Clutch size group (see Table 1), P : Clutch position,
T : Terminal egg (the last egg of the clutch),
a,b,c : Significant differences among positions within clutch size group, line and trait,
*, ** : Significant differences between lines at $p<0.05$ and $p<0.01$, respectively.
High line and Low line refer to hens selected for high and low yolk-albumen ratios.

showed the heaviest shell weights in most clutch size groups, except for groups 1 and 3 of the high line. The changes in egg-shell strength and egg-shell thickness were similar to the changes in egg-shell weight. The largest values of shell strength were mostly observed in the terminal eggs. The terminal eggs also had a thicker egg shell than the other eggs in the same clutch for both lines.

Discussion

Egg laying seems to show a clutch pattern. Most eggs are laid in the day time, and the 1st egg of a clutch is laid at about 90 min after light. The longer the clutch, the earlier the first egg of the clutch was laid. LAG was relatively large for the 2nd egg and decreased for subsequent eggs. However, at the end of each clutch, the oviposition time tended to be lagged with a maximum interval of about 4~5 hours, and the

Table 4. Means ± SD of thick and thin albumen weights

		Thick albumen weight (g)			Thin albumen weight (g)		
G	P	High line		Low line	High line		Low line
1	1	15.7±2.8ᵃ		15.4±1.5ᵃ	14.2±2.5ᵃ	**	18.0±1.9ᵃ
	2	15.0±1.9ᵃ		14.4±1.2ᵃᵇ	14.5±2.3ᵃ	**	16.7±1.5ᵇ
	T	14.6±1.9ᵃ		13.5±2.0ᵇ	14.6±1.8ᵃ	**	17.4±1.1ᵃᵇ
2	1	14.2±1.9ᵃ	**	15.4±2.3ᵃ	15.6±1.9ᵃ	**	18.9±2.3ᵃ
	2	13.6±1.8ᵃᵇ	**	15.1±2.3ᵃ	15.4±1.5ᵃ	**	18.3±2.2ᵃ
	3	13.8±1.9ᵃᵇ		14.7±2.4ᵃᵇ	15.0±1.4ᵃ	**	18.3±2.0ᵃ
	T	13.0±1.6ᵇ	*	13.9±2.3ᵇ	15.6±1.5ᵃ	**	18.4±2.1ᵃ
3	1	13.8±1.5ᵃ		15.0±2.2ᵃ	16.3±1.4ᵃ	**	19.8±3.4ᵃ
	2	13.8±1.8ᵃ		14.6±2.1ᵃ	15.7±1.2ᵃᵇ	**	19.3±2.5ᵃ
	3	13.4±1.7ᵃᵇ		14.3±1.8ᵃᵇ	15.2±1.3ᵇ	**	18.9±2.8ᵃ
	4	13.5±1.6ᵃᵇ		13.9±2.0ᵃᵇ	15.8±1.1ᵃᵇ	**	18.3±2.7ᵃ
	5	13.5±1.8ᵃᵇ		13.8±1.8ᵃᵇ	15.5±1.5ᵃᵇ	**	18.7±2.6ᵃ
	6	13.0±1.7ᵃᵇ		13.6±2.1ᵃᵇ	15.9±1.1ᵃᵇ	**	18.3±2.9ᵃ
	T	12.4±1.6ᵇ		13.0±2.0ᵇ	15.9±1.3ᵃᵇ	**	19.3±3.2ᵃ
4	1	13.2±0.9ᵃ	**	16.5±1.6ᵃ	16.4±1.4ᵃ	**	20.2±3.2ᵃ
	2	13.4±1.1ᵃ	*	15.3±1.9ᵃᵇ	15.8±1.9ᵃ	**	20.0±3.5ᵃ
	3	13.1±0.9ᵃ	*	15.2±2.2ᵃᵇ	15.5±1.5ᵃ	**	19.6±2.7ᵃ
	4	12.9±0.9ᵃ	*	15.1±2.2ᵃᵇ	15.7±1.5ᵃ	**	18.7±2.2ᵃ
	5	12.8±0.7ᵃ	*	14.6±1.8ᵇ	16.1±1.4ᵃ	**	18.9±2.4ᵃ
	6	13.2±1.2ᵃ	*	15.0±1.8ᵇ	15.7±1.5ᵃ	**	19.4±2.6ᵃ
	7	13.5±4.1ᵃ		14.7±1.9ᵇ	14.9±4.5ᵃ	**	19.4±2.6ᵃ
	8	12.9±0.7ᵃ		14.7±2.1ᵇ	15.5±1.4ᵃ	**	20.0±3.1ᵃ
	9	12.8±1.6ᵃ	*	14.7±1.9ᵇ	15.8±1.3ᵃ	**	19.0±2.5ᵃ
	T	12.3±1.1ᵃ	*	14.2±2.3ᵇ	16.0±2.2ᵃ	**	19.1±2.2ᵃ

G : Clutch size group (see Table 1). P : Clutch position.
T : Terminal egg (the last egg of the clutch).
a,b : Significant differences among positions within clutch size group, line and trait.
*,** : Significant differences between lines at $p<0.05$ and $p<0.01$, respectively.
High line and Low line refer to hens selected for high and low yolk-albumen ratios.

clutch terminated by one pause-day in the next day. This laying pattern is similar in both high and low lines, which can produce different egg compositions (Miyoshi *et al.*, 1996 b).

As for changes in egg weight and egg component traits, the first egg of the clutch had the heaviest weight and then egg weight decreased as the serial number within a clutch increased. Choi *et al.* (1981) reported that the mean egg weight of eggs collected in the morning was heavier than that of the eggs collected in the afternoon because most of the 1st eggs in the clutches were laid in the morning. These changes in the egg weight within a clutch may be explained by the physiological condition of the hens. In the beginning cycle of a clutch, the hen may resume her physiological state and has the ability to produce a heavier egg. However, this physiological condition is

Table 5. Means ± SD of egg-shell weight, egg-shell strength, and egg-shell thickness

G	P	Egg-shell weight (g)		Egg-shell strength (kg/cm²)		Egg-shell thickness (g)	
		High line	Low line	High line	Low line	High line	Low line
1	1	5.24 ± 0.50^{a}	5.51 ± 0.51^{a}	1.92 ± 0.88^{a}	2.31 ± 0.50^{b}	0.288 ± 0.031^{a}	0.290 ± 0.029^{b}
	2	5.22 ± 0.41^{a}	* 5.49 ± 0.22^{a}	2.23 ± 0.96^{a}	2.50 ± 0.40^{ab}	0.285 ± 0.022^{a}	0.297 ± 0.017^{b}
	T	5.21 ± 0.41^{a}	* 5.67 ± 0.50^{a}	2.45 ± 0.88^{a}	2.88 ± 0.84^{a}	0.289 ± 0.028^{a}	** 0.321 ± 0.029^{a}
2	1	5.22 ± 0.49^{ab}	** 5.68 ± 0.47^{ab}	2.16 ± 0.70^{b}	* 2.46 ± 0.63^{b}	0.281 ± 0.035^{b}	** 0.301 ± 0.029^{b}
	2	5.20 ± 0.41^{ab}	** 5.71 ± 0.50^{ab}	2.36 ± 0.58^{b}	2.50 ± 0.61^{b}	0.284 ± 0.027^{b}	** 0.304 ± 0.023^{b}
	3	5.15 ± 0.33^{b}	** 5.62 ± 0.48^{b}	2.31 ± 0.59^{b}	2.33 ± 0.61^{b}	0.279 ± 0.023^{b}	** 0.299 ± 0.022^{b}
	T	5.37 ± 0.41^{a}	** 5.87 ± 0.42^{a}	2.69 ± 0.63^{a}	2.94 ± 0.57^{a}	0.298 ± 0.027^{a}	** 0.322 ± 0.021^{a}
3	1	5.48 ± 0.57^{a}	5.54 ± 0.30^{ab}	2.26 ± 0.59^{a}	2.37 ± 0.86^{b}	0.300 ± 0.039^{ab}	0.295 ± 0.019^{b}
	2	5.40 ± 0.60^{a}	5.63 ± 0.38^{ab}	2.50 ± 0.83^{a}	2.48 ± 0.70^{b}	0.300 ± 0.039^{ab}	0.302 ± 0.017^{b}
	3	5.21 ± 0.52^{a}	* 5.57 ± 0.41^{ab}	2.34 ± 0.80^{a}	2.30 ± 0.54^{b}	0.286 ± 0.026^{b}	0.296 ± 0.018^{b}
	4	5.25 ± 0.45^{a}	5.39 ± 0.36^{b}	2.18 ± 0.50^{a}	2.32 ± 0.77^{b}	0.289 ± 0.024^{ab}	0.297 ± 0.016^{b}
	5	5.24 ± 0.46^{a}	5.37 ± 0.40^{b}	2.32 ± 0.75^{a}	2.44 ± 0.36^{b}	0.286 ± 0.026^{b}	0.290 ± 0.017^{b}
	6	5.19 ± 0.53^{a}	5.43 ± 0.39^{b}	2.32 ± 0.60^{a}	2.45 ± 0.55^{b}	0.284 ± 0.028^{b}	0.297 ± 0.025^{b}
	T	5.48 ± 0.59^{a}	5.81 ± 0.47^{a}	2.64 ± 0.69^{a}	* 3.07 ± 0.53^{a}	0.310 ± 0.037^{a}	0.326 ± 0.026^{a}
4	1	5.30 ± 0.55^{ab}	* 5.87 ± 0.54^{a}	2.05 ± 0.46^{ab}	2.08 ± 0.71^{b}	0.292 ± 0.037^{ab}	0.297 ± 0.027^{b}
	2	5.24 ± 0.39^{ab}	* 5.82 ± 0.61^{a}	2.18 ± 0.62^{ab}	2.25 ± 0.44^{b}	0.291 ± 0.027^{ab}	0.303 ± 0.030^{b}
	3	5.18 ± 0.38^{ab}	* 5.67 ± 0.51^{a}	2.13 ± 0.53^{ab}	2.09 ± 0.47^{b}	0.283 ± 0.020^{b}	0.294 ± 0.020^{b}
	4	5.19 ± 0.44^{ab}	* 5.70 ± 0.51^{a}	1.93 ± 0.68^{ab}	2.08 ± 0.44^{b}	0.283 ± 0.026^{ab}	0.294 ± 0.018^{b}
	5	5.11 ± 0.42^{ab}	** 5.69 ± 0.48^{a}	1.97 ± 0.76^{ab}	2.13 ± 0.30^{b}	0.284 ± 0.019^{ab}	0.302 ± 0.024^{b}
	6	5.08 ± 0.38^{ab}	** 5.64 ± 0.48^{a}	2.14 ± 0.68^{ab}	1.98 ± 0.46^{b}	0.274 ± 0.020^{ab}	* 0.297 ± 0.020^{b}
	7	5.15 ± 0.32^{ab}	* 5.63 ± 0.47^{a}	2.05 ± 0.36^{ab}	2.03 ± 0.45^{b}	0.284 ± 0.018^{b}	0.297 ± 0.026^{b}
	8	5.02 ± 0.26^{ab}	** 5.61 ± 0.44^{a}	1.81 ± 0.56^{b}	2.12 ± 0.70^{b}	0.281 ± 0.011^{ab}	0.297 ± 0.021^{b}
	9	4.91 ± 0.40^{b}	** 5.54 ± 0.46^{a}	2.06 ± 0.51^{ab}	2.31 ± 0.55^{b}	0.270 ± 0.025^{b}	** 0.298 ± 0.024^{b}
	T	5.42 ± 0.54^{a}	* 5.91 ± 0.50^{a}	2.56 ± 0.55^{a}	2.80 ± 0.37^{a}	0.302 ± 0.026^{a}	* 0.325 ± 0.028^{a}

G : Clutch size group (see Table 1), P : Clutch position,
T : Terminal egg (the last egg of the clutch),
a,b : Significant differences among positions within clutch size group, line and trait,
*, ** : Significant differences between lines at $p<0.05$ and $p<0.01$, respectively.
High line and Low line refer to hens selected for high and low yolk-albumen ratios.

gradually lost for subsequent eggs in a clutch. Even when the oviposition interval for the terminal egg is the longest, the weight of this egg is not the heaviest. However, the relative changes in egg component traits (yolk weight and shell weight) do not follow the pattern of changes in egg weight. The yolk of the second egg in a clutch tends to be larger than the others. ARAFA *et al.* (1982) stated that eggs laid at 10 : 00 AM had heavier egg weights than eggs laid at other times in the day. The changes in albumen weight within a clutch reflect the dependent change of egg weights by albumen weights, in which thick albumen may be more important. Non-accordant changes in thin albumen weight for eggs laid later in the clutch may be regarded as a stagnation of the decrease in albumen of these eggs. Significant differences in the thin albumen weight between lines may be the main cause for differences in albumen weight between lines. However, thin albumen could not be cumulated when the albumen was being secreted at the magnum of the oviduct (SATO ; 1980). Therefore, this large difference in the thin albumen weight between lines might be due to water passing into the egg at the shell gland of the oviduct (called plumping) in the low line that had more total albumen. Moreover, the increase in thin albumen in eggs laid at later positions of the clutch can also be explained by the phenomenon of plumping, because these eggs are expected to stay longer at the shell gland of the oviduct.

The change in shell weight is a reflection of the change in shell thickness and strength. This is indicated by the results presented in Table 5 that the terminal eggs had the heaviest shell weight, and the highest values of shell strength and shell thickness were also observed for the terminal eggs. These changes in egg shell traits in the present study are supported by TANABE (1971) that shell weight was positively correlated with shell thickness and shell strength. The results in this study are also in agreement with the report of HASHIGUCHI (1996) that shell weight, shell strength and shell thickness were higher in the first and last eggs of the clutches, especially for large clutch sizes.

As mentioned above, egg components and egg-shell quality showed a large variation in the 1st eggs and the terminal eggs of the clutch, but only a small variation in eggs laid at middle positions of the clutch. This tendency was especially notable in large clutch size groups. Generally, the 1st eggs of the clutches are laid after light early in the morning and the last eggs are laid later in the afternoon. To evaluate egg quality of individual hens or flocks, the collection of eggs can be planned in the morning without the necessity to know the oviposition time.

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採卵鶏におけるクラッチ内の卵構成および卵殻質の変動

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卵黄・卵白比に対して高低2方向への選抜によって造成された高低2系統の鶏群（高系統40羽，低系統39羽）を用い，クラッチ内での卵構成および卵殻質の変動を検討した。約270日齢において5：30から18：30まで30分毎に放卵時刻を90日間調査した。採卵は1羽より3つのクラッチを目標として毎日行った。放卵時刻からクラッチポジションの明確な卵の測定値のみを用い，クラッチの長さにより4グループに分けて分析した。

放卵間隔の遅れ（LAG）はクラッチの最終卵で最も大きく，放卵間隔には系統間に差異が認められなかった。卵重のクラッチポジションの進行に伴う推移はクラッチの第1卵が有意に重く，徐々に減少する傾向を示した。低系統での減少が大きく（約3～4g），第1卵の約6%に相当した。高系統では約4%に当たる1.5～2.0gの減少であった。卵黄重はクラッチの第2卵が重く，その後減少したが，その減少量は両系統で近似し，1.0～1.5g程度であった。卵白重はクラッチの第3卵および第4卵まで顕著な減少を示し，その後，その減少は停滞する傾向にあった。卵白量の多い低系統での減少が大きく推定された。濃厚卵白重がクラッチポジションの進行に伴い減少傾向にあったのに対し，水様性卵白重はクラッチの後半に位置する卵で若干増加する傾向にあった。卵殻重，卵殻厚および卵殻強度は，クラッチの最終卵において顕著な増加を示した。

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