HERITABILITIES AND GENETIC CORRELATIONS OF EGG QUALITY TRAITS IN TAIWAN'S LOCAL CHICKEN

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Summary

Means and standard errors of 285 Taiwan's local chicken and 429 Single Comb White Leghorn pullets at 35 wk of age were: egg weight (g) 48.3 ± 0.3, 54.6 ± 0.3, shell index 73.39 ± 0.26, 73.20 ± 0.18, shell color 15.23 ± 0.40, 0.88 ± 0.27, shell whiteness 72.61 ± 0.57, 90.00 ± 0.35, shell strength (kg/cm^2) 3.77 ± 0.07, 3.35 ± 0.05, shell thickness (mm) 0.38 ± 0.003, 0.38 ± 0.002, Haugh units 85.26 ± 0.50, 91.81 ± 0.38 and yolk percent (%) 30.17 ± 0.18, 27.32 ± 0.16 respectively.

The estimated heritabilities of Taiwan's local chicken based on sire and dam components of variance were as follows: egg weight 0.20, shell index 0.1, shell color 0.87, shell whiteness 0.79, shell strength 0.37, shell thickness 0.14, Haugh units 0.24 and yolk percent 0.16. Genetic correlations based on sire and dam components of variance and covariance were also estimated. Generically, the shell index was positively correlated with egg weight, shell strength and yolk percent, and egg weight was negatively correlated with shell thickness, Haugh unit and yolk percent.

(**Key Words**: Heritability, Genetic Correlation, Egg Quality, Taiwan's Local Chicken)

Introduction

In many developing countries a majority of the production still consists of local type chicken. Recently, many reports pointed out local chicken could be utilized (Huang et al., 1992; Horst et al., 1992; Mukherjee, 1992), because these chicken generally had better disease resistance, heat-resisting, better meat and egg qualities. In Taiwan, the consumer would pay a higher price for this chicken; and eggs from local chickens could be sold at about 20-25% higher price compared to white eggs from commercial hybrids in India (Khare, 1987). But local chicken were seldom selected, they had poor production efficiency and more variation, as has been suggested by Horst et al. (1992).

The literature on pertinent heritabilities is presented in table 1, genetic correlations in table 2. In general, most reported heritabilities of egg quality are high. Either maternal or dominance effects, or both, are suggested by the fact that the maternal half-sib estimates are higher than the paternal half-sib estimates for egg weight, shell index and shell color. Egg weight tended to be negatively correlated with Haugh unit, shell index and yolk percent. Shell index and Haugh unit were positively correlated. Most of the chicken studied in the literatures were egg-type or dual-purpose breeds, they should have been selected for egg quality traits for sometime. But local chicken was seldom selected. Therefore, whether the unselected local chicken has more genetic variation than the improved breeds?

Because the local chicken represents more than half of the meat-type chicken in Taiwan, the National Chung Hsing University has been improving these chicken for a few years. Several lines of chicken have been formed and selected for earlier sexual maturity and/or egg production (Lee, 1990). No effort have been done to improve egg quality traits. In order to study whether the genetic parameters of egg quality traits of the local chicken would be different from the improved egg laying breeds, two strains of Single Comb White Leghorn from the Taiwan Livestock Research Institute were also studied.

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TABLE 1. REPROTED HERITABILITY ESTIMATES OF EGG QUALITY TRAITS

Age and breed[1] of chicken		Heritability Estimate S	D	S + D	Reference
		····· Egg weight ·····			
31-32 wk	WLX's	.50		.47	Dickerson (1957)
36 wk	WL			.32	Zhang (1984)
36 wk	WL	.53±.25			Maan et al. (1983)
40 wk	WL			.13±.90	Atkare and Khan (1988)
41 wk	WL			.45±.16	Potts et al. (1985)
68-80 wk	WL			.65±.14	Engstrom et al. (1986)
34 wk	WL	.71±.15	.35±.11	.53±.09	Poggenpoel (1986)
35 wk	BL			.87	Van Drunen et al. (1992)
40 wk	RIR	.63±.25	.55±.18	.59±.15	Mohapatra et al. (1985)
40 wk	WG	.72	.29	.50	Goodmam et al. (1961)
27 wk	F			.06±.16	Atalla et al. (1983)
? wk	RC	.13±.18	.99±.27		Mishra et al. (1986)
? wk	B	.41±.20			Singh et al. (1988)
Average		.52	.55	.46	
		····· Shell index ·····			
31-32 wk	WLX's	.27		.30	Dickerson (1957)
36 wk	WL	.51±.25			Maan et al. (1983)
40 wk	WG	.51	.18	.35	Goodman et al. (1961)
? wk	RC	.16±.18	.83±.23		Mishra et al. (1986)
Average		.36	.51	.33	
		····· Shell strength ·····			
41 wk	WL			.18±.09	Potts et al. (1985)
55 wk	WL			.48±.05	Garwood et al. (1979)
? wk	WL			.53	Torges (1963)
35 wk	BL			.27	van Drunen et al. (1992)
Average				.37	
		····· Shell colour ·····			
? wk	WL	.48	.43		Gowe et al. (1965)
35 wk	BL			.49	Van Drunen et al. (1992)
? wk	S	.24±.17	.65+.20	.45±.11	Hunton (1962)
Average		.36	.54	.47	
		····· Shell thickness ·····			
34 wk	WL	.45±.09	.29+.09	.37±.06	Poggenpoel (1986)
40 wk	RIR	.31±.16	.34±.18	.33±.11	Mohapatra et al. (1985)
Average		.38	.32	.35	
		····· Haugh units ·····			
34 wk	WL	.51±.10	.28±.09	.40±.06	Poggenpoel (1986)
36 wk	WL	.28±.21			Maan et al. (1983)
40 wk	RIR	.26±.15	.44±.19	.35±.11	
Average		.35	.36	.38	
		····· Yolk percent ·····			
32 wk	WL	.20+.08			Jaffe (1964)
? wk	WL	.48	.04		Kenneth et al. (1959)
Average		.34	.04		

[1] X's refers to crosses. WL, White Leghorn. BL, Brown Leghorn. RIR, Rhode Island Red. WG, White Gold. F, Fayoumi Chicken. RC, Red Cornish. B, Broiler. S, Sussex.

TABLE 2. REPROTED GENETIC CORRELATION ESTIMATED OF EGG QUALITY TRAITS

Trait, Age and breed of chicken	Basis of estimate	Genetic correlation	Reference
	..... Egg weight with		
Haugh unit, 32 wk, WL	S + D	−1.48	Steven et al. (1961)
Haugh unit, 34 wk, WL	S + D	0.03±.10	Poggenpoel (1986)
Haugh unit, 40 wk, RIR	S + D	0.14±.19	Mohapatra et al. (1985)
Shell index, ? wk, B	S	−0.55±.21	Singh et al. (1988)
Shell index, ? wk,		0.07	Kinney et al. (1968)
Shell strength, 41 wk, WL	S + D	0.06	Potts et al. (1985)
Shell thickness, 34 wk, WL	S + D	0.22±.11	Poggenpoel (1986)
Shell thickness, 40 wk, RIR	S + D	0.16±.19	Mohapatra et al. (1985)
Yolk percent, 32 wk, WL	S	−1.004	Jaffe (1964)
	..... Haugh unit with		
Shell index, 36 wk, WL	S	0.60±.26	Maan et al. (1983)
Shell thickness, 40 wk, RIR	S + D	−0.38±.20	Mohapatra et al. (1985)
Shell thickness, 34 wk, WL	S + D	0.13±.11	Poggenpoel (1986)
Yolk percent, ? wk, WL	S + D	−0.38	Kenneth et al. (1959)

Materials and Methods

Breed and Management of Birds

There were two flocks being used in this study. One was Taiwan's local chicken, the other was Single Comb White Leghorn. Taiwan's local chicken was obtained from the National Chung-Hsing University which included five lines (Y, L1, L2, B and S lines) seleted for egg production before 40 wk of age and/or earlier sexual maturity. Single Comb White Leghorn was obtained from Taiwan Livestock Research Institute which selected for egg production (P line) and egg weight (E line), the two flocks were described in detail by Lee et al. (1989). Pedigreed egg were produced by artificial insemination. Eggs were collected and hatched on the 12th of December in 1985 and on the 1st of May in 1986, and the number of birds used is shown in tabel 3. Upon hatching, chicks were wingbanded and vaccinated for Marek's disease. They were housed in litter floor pens and were *ad libitum* fed a starter diet (2,800 kcal ME/kg and 18.7% CP) to 6 wk of age. The birds were fed pre-grower diet (2,800 kcal ME/kg and 16.8% CP) from 7 wk of age to 14 wk of age, post-grower diet (2,900 kcal ME/kg and 12.0% CP) from 15 wk of age to 20 wk of age, and laying mash (2,840 kcal ME/kg and 14.7% CP) for the remainder of the experiment. The pullets were moved to the individual cages of laying house at 17 wk of age. Natural lighting was used until the pullets were 21 wk of age. The birds of first hatching were provided with 15.5 h of light after 21 wk of age, and the second with 14 h. Egg production and mortality were recorded daily from 17 to 69 wk.

Traits measured

The egg quality traits were measured during 25, 35 and 65 wk of age. All egg quality measurements were taken on the day after being laid. Albumen quality, measured in Haugh units (Haugh, 1937). Egg yolk percent = (yolk weight/egg weight) × 100%. Shell index was the width/length ratio (maximum width of the egg × 100/length of the egg). Shell strength were obtained using the FHK loader (FHK, made in Japan) which measured the pressure needed to break the shell. The thickness of the shell was the average of the blunt, middle and sharp points of the egg. Tint of the egg shell measured by a colorimeter (Σ 80 COLOR MEASURING SYSTEM), which determine the so-celled L, a and b values. When L is 100, the shell color is white, while L = 0, indicates the shell color is black. Shell whiteness is calculated by $100 \sqrt{[(100-L)^2 + (a^2+b^2)]}$, and shell colour is calculated by $\sqrt{(a^2+b^2)}$.

TABLE 3. NUMBER OF BIRDS USED IN THE STUDY

	Taiwan local chicken						Single Comb White Leghorn		
	Y	L1	L2	B	S	Total	P	E	Total
	····· First hatch (hatched on Dec. 12, 1985)·····								
Sire	3	4	6	4	3	20	25	28	53
Dam	7	10	18	12	9	56	74	78	152
Pullet	24	19	48	28	24	143	118	120	238
	····· Second hatch (hatched on May 1, 1986) ·····								
Sire	4	6	9	–	–	19	22	20	42
Dam	16	24	24	–	–	64	59	58	117
Pullet	39	63	40	–	–	142	95	96	191

Genetic Analysis

Variance and covariance components of the traits (Y_{ijklm}) were calculated based on the model: $Y_{ijklm} = \mu + B_i + L_{ij} + S_{ijk} + d_{ijkl} + e_{ijklm}$, where μ is the overall mean, B_i is the effect of the ith breed, L_{ij} is the effect of the jth line within breed$_i$, S_{ijk} is the effect of the kth sire within the jth line within breed$_i$, d_{ijkl} is the effect of the ith dam within the kth sire within the jth line within breed$_i$, and e_{ijklm} is the random component particular to the mth progeny of the ith dam and the kth sire of the jth line within the ith breed. The heritabilities, genetic correlations and standard error were calculated by the estimated variance and covariance components as described by Becker (1984). All variances and covariances were accomplished using the TYPE1 METHOD of the VARCOMP and NESTED procedure from SAS (SAS Institute, 1988).

Results and Discussion

Breed Differences

The means and coefficients of variation (%) for egg quality by breed are shown in tables 4 and 5, respectively. The egg weight and Haugh unit of the local chicken were significantly smaller than Single Comb White Leghorn's, but shell strength were stronger and yolk percent were larger. Small egg, strong egg shell and large yolk percent were also common characteristics in other local chickens (Horst, 1988; Mukherjee, 1992; Nwosu, 1992). It is interesting to note that the egg shell strength of the local chicken was higher than White Leghorn especially in the late laying period (65 wk), but the shell thickness was not significantly different between two breeds.

Coefficients of variation of the local chicken's egg traits were in general larger than those of

TABLE 4. COMPARISONS OF MEANS OF EGG QUALITY TRAITS BETWEEN TAIWAN LOCAL CHICKEN AND SINGLE COMB WHITE LEGHORN AT DIFFERENT WEEKS OF AGE

Traits	Taiwan local chicken			Single Comb White Leghorn		
age (week)	25	35	65	25	35	65
Egg weight (g)	40.9	48.3	55.9	48.1	54.6	63.9
Shell index (%)[1]	74.81	73.39^{ns}	73.03^{ns}	73.33	73.20	73.24
Shell strength (kg/cm^2)	3.96	3.77	3.41	3.46	3.35	2.86
Shell color	–[2]	15.23	13.07	–	0.88	0.74
Shell whiteness	–	72.61	73.98	–	90.00	88.25
Shell thickness (mm)	0.34^{ns}	0.38^{ns}	0.35^{ns}	0.35	0.38	0.35
Haugh unit	88.07	85.26	84.71	94.19	91.81	90.29
Yolk percent (%)	27.06	30.17	32.14	24.59	27.32	29.58

[1] Except for those figures with ns superscripts, all the means at the same age between two breeds are significantly different ($p < 0.05$).

[2] Not measured.

the White Leghorn, except the shell color which was possibly caused by the very small mean (table 4). There were more variations of egg shape existed in the local chicken, but C.V. (%) of shell index was not significantly different between two breeds. Eggs with the same shell index might have different shapes. To reveal the difference in the uniformity of egg shapes, we need a new parameter. If we use a cylinder to load the egg, the cylinder should have a diameter equals to the width of the egg and a height equals to the length of the egg. Eggs with the same shell index could be loaded in the same cylinder, but the ratio of the egg weight to the volume of the cylinder might be different among eggs with different egg shapes. Eggs with more varied egg shapes should have more variation in their egg weight/cylinder volume ratio. The hypothesis appears to be true that the C.V. of the egg weight/cylinder volume ratio in the local chicken was always larger than that of the Single Comb White Leghorn (table 5).

TABLE 5. COEFFICIENT OF VARIATION (%) OF EIGHT EGG QUALITY TRAITS AT DIFFERENT WEEKS OF AGE

Traits	Taiwan local chicken			Single Comb White Leghorn		
age (week)	25	35	65	25	35	65
Egg weight	10.4	9.4	11.2	9.2	9.9	8.5
Shell index	5.20	4.88	4.97	4.46	4.72	5.27
(Egg weight/cylinder)	5.14	7.18	4.09	2.51	6.30	3.58
Shell strength	26.77	24.10	26.69	26.59	25.97	28.32
Shell color	–[1]	23.64	31.14	–	81.82	87.84
Shell whiteness	–	7.18	8.26		1.61	2.58
Shell thickness	10.92	10.14	15.97	9.14	8.37	9.19
Haugh unit	8.41	7.73	8.39	6.83	6.64	6.71
Yolk percent	8.17	7.78	7.31	7.89	6.99	7.17

[1] Not measured.

Heritability

Table 6 shows estimates of the heritabilities and standard error of egg quality traits at 35 wk of age. In general, the h^2_D of egg outer qualities (such as egg weight, shell index and shell strength) were higher than the h^2_S, the maternal and dominance effects on egg outer traits seemed to be important; and for shell color, major genes are probably segregating in local flocks, some of which may be acting in a dominant manner as suggested by Hunton (1962). Oppositely, the h^2_D of egg inner qualities (such as Haugh unit and yolk percent) were lower than h^2_S.

Estimated heritabilities of Single Comb White Leghorns (table 6) were similar to the reported figures (table 1). However, those of the local chicken were somewhat lower, except the shell strength and tints of egg shell. Fayoumi was the only one local breed in table 1 and its heritability of egg weight was also very low. No evidence in this study to show that our local chicken had more genetic variation than the Single Comb White Leghorns. However, the local chicken had large environmental variance, except the egg weight. Environmental variances of the local chicken and the Single Comb White Leghorns were: shell index (11.92 vs. 8.53), shell thickness (0.0015 vs. 0.0009), Haugh unit (38.76 vs. 30.84) and yolk percent (5.01 vs. 2.70). These suggest that local chicken's performance could be improved simply through improving rearing environment.

Correlations

The phenotypic and genetic correlations between egg traits are presented in table 7. These estimates are based on both sire and dam components (SD). The phenotypic correlations of egg weight with other traits (shell index, color, whiteness, strength and Haugh unit) were low and insignificant, ranging from −0.04 to 0.19. Potts et al. (1985) suggested that correlations between shell strength and egg weight at 41, 60, 68 or 77 wk were near zero. Low phenotypic correla-

TABLE 6. HERITABILITIES (±S.E.) OF EIGHT EGG QUALITY TRAITS AT 35 WEEKS OF AGE

Traits	Taiwan local chicken			Single Comb White Leghorn		
	S[1]	D	SD	S	D	SD
Outer qualities						
Egg weight	.07±.26	.33±.49	.20±.22	.05±.20	.83±.44	.44±.20
Shell index	−.23±.22	.43±.53	.10±.22	.42±.23	.73±.40	.58±.19
Shell strength	.23±.29	.51±.48	.37±.23	.15±.20	.44±.44	.30±.21
Shell color	.37±.53	1.4 ±.74	.87±.35	.18±.32	.12±.66	.15±.30
Shell whiteness	.41±.52	1.2 ±.72	.79±.35	.26±.29	−.76±.70	−.25±.33
Shell thickness	.28±.27	.01±.49	.14±.24	.12±.20	.34±.45	.23±.21
Inner qualities						
Haugh unit	.30±.28	.18±.47	.24±.23	.65±.24	.04±.40	.35±.20
Yolk percent	.24±.27	.07±.48	.16±.23	.52±.24	.54±.40	.53±.20

[1] Based on sire (S), dam (D) and both (SD) components of variance.

TABLE 7. CORRELATIONS OF EIGHT EGG TRAITS AT 35 WEEKS OF AGE OF LOCAL CHICKEN

Traits	Egg weight	Shell index	Shell color	Shell whiteness	Shell strength	Shell thickness	Haugh unit	Yolk percent
Egg weight		2.26	0.23	−0.34	−0.24	−0.94	−0.62	−0.41
Shell index	−0.04		0.46	−0.47	1.13	−0.58	0.47	2.41
Shell color	0.08	0.03		−1.20	0.43	0.52	−0.19	−0.40
Shell whiteness	−0.12	−0.07	−0.93		−0.19	−0.55	0.14	0.14
Shell strength	0.19	0.21	−0.03	−0.02		0.87	- 0.35	0.49
Shell thickness	0.31	0.24	−0.02	−0.03	0.47		−0.16	1.90
Haugh unit	−0.03	0.23	0.10	−0.10	−0.01	−0.03		0.60
Yolk percent	−0.36	−0.04	- 0.08	0.09	0.01	−0.19	- 0.27	

Below the diagonal are phenotypic correlations, above the diagonal are genetic correlations.

tions between egg weight and shell shape were also observed in New Hampshire and Leghorn by Hicks (1958). The correlations value for egg weight with shell thickness and yolk percent were medium (0.31 and −0.36) and significant. The correlation (0.47) between shell thickness and shell strength was significant and was in agreement with the findings of Potts et al. (1974); Hunton (1969) and Richards et al. (1967). For the other egg quality traits, phenotypic correlations were low.

There were high positive genetic correlation between egg weight and shell index, between shell index and shell strength, between shell strength and shell thickness, between shell index and yolk percent, and between shell thickness and yolk percent. Combs et al. (1979) produced a high-breaking-strength and a low-breaking-strength line after two generations of selection. The percent shell weight and shell thickness of low-strength line was significantly lower than that of the high-strength line. Van Toledo et al. (1980) also reported that after four generations selected for egg shell strength, egg shell thickness from the high shell strength line was significantly different from low shell strength line. The high negative genetic correlations between shell color with shell whiteness and egg weight with shell thickness were −1.20 and −0.94 respectively.

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Literature Cited

Atalla, A. A., F. K. R. Stino, N. E. Goher and G. A. R. Kamar. 1983. Genetics of egg cholesterol and related characteristics in Fayoumi chickens. Egyptian J. Anim. Prod. 23:133-142.

Atkare, S. S. and A. G. Khan. 1988. Relationship between part egg production records, body weight and egg weight in IWM strain of White Leghorn breed. Indian J. Anim. Sci. 58:361-365.

Becker, W. A. 1984. Manual of Quantitative Genetics. 4th ed. Academic Enterprises, Pullman, WA.

Combs, G. E., Jr., A. H. Parsons and M. B. Ross. 1979. Calcium homeostasis in pullets of two lines selected for differences in egg shell strength. Poult. Sci. 58:1250-1256.

Dickerson, G. E. 1957. Genetic variation in some economic characters of leghorn-type chicken. Poult. Sci. 36:1113. (abstract).

Engstrom, G. C. Weyde and L. E. Liljedahl. 1986. Genetic correlations and heritabilities for frequency of craked eggs, egg number and egg weight in laying hens. Br. Poult. Sci. 27:55-61.

Garwood, V. A., P. C. Lowe and C. G. Haugh. 1979. Method for improving egg shell strength by selection. Br. Poult. Sci. 20:289-295.

Goodman, B. L. and R. G. Jaap. 1961. Non-additive and sex-linked genetic effects on egg production in a randombred population. Poult. Sci. 40:662-668.

Gowe, R. S., H. W. Budde and P. J. McGann. 1965. On measuring egg shell color in poultry breeding and selection programs. Poult. Sci. 44:264-270.

Haugh, R. R. 1937. The Haugh unit for measuring egg quality. U. S. Egg Poult. Mag. 43:552-555, 572-573.

Hicks, A. F., Jr. 1958. Heritability and correlation analyses of egg weight, egg shape and egg number in chicken. 37:967-975.

Horst, P. 1988. Native fowl as reservoir for genomes and major genes with direct and indirect effects on productive adaptability. Proceedings XVII world's Poultry Congress, Symposia, pp. 99-105.

Horst, P. and P. K. Mathur. 1992. Trends in economic values of selection traits for local egg production. Proceedings XIX World's Poultry Congress, Symposia 2:577-583.

Huang, H. H. and Y. P. Lee. 1992. Commercial production of local chickens in Taiwan. Proceedings XIX World's Poultry Congress, Symposia. 2:618.

Hunton, P. 1962. Genetics of egg shell colour in a light sussex flock. Br. Poult. Sci. 3:189-193.

Hunton, P. 1969. The measurement of egg shell strength. A comparison of four methods. Br. Poult. Sci. 10:281-289.

Jaffe, W. P. 1964. The relationship between egg weight and yolk weight. Br. Poult. Sci. 5:295-298.

Kenneth, T. S. and J. L. Skirner. 1959. Heritability and genetic correlations of albumen weight and yolk size in chicken eggs. Poult. Sci. 38:1262. (abstract).

Khare, S. P. 1987. Statistical investigation into pricing behaviour of some egg markets in India. Pulbication No. 28, Div. of Post harvest tech. CARI, Izatnagar, India.

Kinney, T. B., Jr. and P. C. Lowe. 1968. Genetic and phenotypic variation in the regional redcontrols over nine years. Poults. Sci. 47:105-110.

Lee, Y. P. and H. H. Huang. 1989. Improvement and utilization of genetic resources in native chicken: reciprocal cross between Taiwan Country Chicken and Single Comb White Leghorn. Asian-Aust. J. Anim. Sci. 2:103-114.

Lee, Y. P. 1990. Development and improvement of native chickens in Taiwan. Proc. 5th AAAP Anim. Sci. Cong. Vol. 1 pp. 349-353.

Maan, R. S., R. K. Sharma, B. S. Chhikara and V. K. Tanwar. 1983. Studies on some egg quality traits and their relationship with some production traits. Haryana Agric. Univ. J. Res. 13:191-194.

Mishra, P. K., S. C. Mishra, P. Panda, P. K. Dehuri, S. K. Chand and M. K. Bala. 1986. Heritabilities for egg weight and shape index in a Red Cornish flock. Indian J. Poult. Sci. 21:264-265.

Mohapatra, G. S., B. N. Patro, G. L. Jain and B. K. Mohanty. 1985. Estimates of genetic parameters for some egg production and egg quality traits in a Rhode Island Red flock. Indian J. Poult. Sci. 20:4-7.

Mukherjee, T. K. 1992. Usefulness of indigenous breeds and imported stocks for poultry production in hot climates. Proceedings XIX World's Poultry Congress, Symposia. 2:31-37.

Nwosu, C. C. 1992. Genetics of local chickens and its implications for poultry breeding. Proceedings XIX World's Poultry Congress, Symposia. 2:38-42.

Poggenpoel, D. G. 1986. Correlated response in shell and albumen quality with selection for increased egg production. Poult. Sci. 65:1633-1641.

Potts, P. L. and Sr., K. W. Washburn. 1985. Genetic variation in shell strength and its relationship to egg size. Poult. Sci. 64:1249-1256.

Potts, P. L. and Sr., K. W. Washburn. 1974. Shell evaluation of white and brown egg strains by deformation, breaking strength, shell thickness and specific gravity, 1. Relationship to egg characteristics. Poult. Sci. 53:1123-1128.

Reddy, C. V. 1991. Poultry production in developing versus developed countries. Misset. World Poult. 7(1):8-9.

Richards, J. F. and L. M. Staley. 1967. The relationship between crushing strength, deformation and other physical measurements of the hen's egg. Poult. Sci. 46:430-437.

SAS Institute. 1988. SAS® User's Guide: Statistics Release 6.03 ed. SAS Institute Inc., Cary, NC. U.S.A.

Singh, A., R. P. Singh and J. Kumar. 1988. Genetic analysis of egg quality traits in meat type chicken. Indian J. Poult. Sci. 23:212-217.

Steven, C. K., J. D. Mitchell, W. H. Kyle and W. J. Stadelman. 196[illegible]. Egg quality genetic variation and

covariation. Poult. Sci. 40:965-975.

Torres, H. G. 1963. Investigations on the degree of inheritance in egg quality characters, egg albumen index, breaking strength of the shell and yolk colour. Anim. Breeding Abs. 32:2457. (Abstract).

Van Drunen, C. P. and A. J. C. Groot. 1992. Genetic parameters of shell quality assays in layers. Proceedings XIX World's Poultry Congress, Symposia. 3:120.

Van Toledo, B., A. H. parsons and G. F. Combs, Jr. 1980. Mammillary structure as a determinant of egg shell strength. Poult. Sci. 59:1667. (abstract).

Zhang, L. 1984. Genetic analysis of some quantitative traits of Beijing White Leghorn III birds. Acta. Veterinaria et Zootechnica Sinica. 15:33-38.