HERITABILITY OF PHYSIOLOGICAL CHARACTERS OF CHICKENS

III. Serum Alkaline Phosphatase Activity and its Relation to Growth

By

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As one of the studies on heritability in relation to the physiological and biochemical characteristics of the chicken, heritability estimates of the weights of a few endocrine organs and the hemoglobin and reduced glutathione levels in blood, have been reported at this laboratory (MATSUMOTO *et al.*, 1958 *a*, *b*). Since the heritabilities of these characteristics were comparatively high (for example, 0.43 for thyroid weight and 0.45 for hemoglobin level), to investigate the degree of heritability in relation to such characteristics would be of interest for poultry breeding.

The individual variation in the serum alkaline phosphatase activity of fowls was noted by AUCHINACHIE & EMSLIE (1934) and PETERSON & PARRISH (1939 *b*). The results of the former indicated that the normal range in female was wider than that in male, while the latter reported that the value for cockerels varied as much as that for pullets. However, they did not analyse the matter concerning the genetic control of this characteristic except that the breed differences only were noted by the former.

Recently, KUNKEL *et al.* (1953) presented evidence that there are breed differences of serum alkaline phosphatase activity in cattle, and that the repeatability of this activity was low, indicating a considerable effect of environmental factors. It was also suggested that the heritable variation in serum alkaline phosphatase was inherited in a strictly additive manner, since the crossbred (*Bos indicus* × *Bos taurus*) showed median values between the two. A highly significant positive correlation between phosphatase activity and subsequent gain in a group of Brahman bulls was presented by KUNKEL *et al.* (1954); later

[Journ. Facul. Agr., Hokkaido Univ., Sapporo, Vol. 51, Pt. 2, 1960]

FLETCHER *et al.* (1956) observed a significant multiple correlation among phosphatase, age, weight, and gain. FLETCHER *et al.* suggested the possibility of making an efficient index to predict the future gain by these characteristics.

In mature chickens, STUTTS *et al.* (1957) reported that the repeatability of plasma alkaline phosphatase activity was highly significant, ranging from 0.6 to 0.9, although, the estimates of heritability were 0.35–0.40 for males, whilst for females they were almost zero.

The objective of the present report is to estimate the degree of heritability of the serum alkaline phosphatase activity of chickens at 5 weeks of age and to investigate the relationship of that activity to body weight and gain. In addition, the change of the genetical control on the body weight from the hatch to the 5th week was studied.

Materials and Methods

The experimental stocks for the present studies were obtained from crossbreds between two closed strains, that is, the B and C strains of Single Comb White Leghorns. The coefficients of inbreeding of the B strain were 12–30%, for the C strain were 7–15%. These strains are maintained by the Takikawa Livestock Breeding Station. The birds used in these studies were 154 male chicks hatched in the spring of 1958. These chicks were sent at once after the hatch from the Takikawa Livestock Breeding Station to this laboratory. They were brooded artificially under homemade electric lamp brooders. The feed used was a ration for chicks purchased from Hokkaido Ryoshoku Co., Ltd. The chicks were weighed at each week of age; they were five weeks of age at the time of experiment.

Blood samples were collected into test tubes through an incision in the carotid. The samples were allowed to clot. The sera were separated by centrifugation, and stored at −10°C until the determinations could be carried out. The analyses were completed within four days of the date of collection of the blood samples.

The serum alkaline phosphatase activity was determined by the para-nitrophenyl phosphate method of BESSEY *et al.* (1946) in which 0.05 ml. of serum was used. The method was modified by using the veronal-HCl buffer at a pH of 9.6 instead of glycine-NaOH buffer. The activity was expressed as "millimole units" which would liberate millimoles of nitrophenol per liter of serum per hour.

Statistical analyses were made according to the method outlined by SNEDECOR (1948). Heritability estimates and genetic correlations were calculated from variance components by the method of LERNER (1950).

Results and Discussion

Shown in Table 1 are the body weights of each chick at each week of age used for analyses from hatch to fifth week and the serum alkaline phosphatase activity at five weeks of age. It will be seen that the change of growth rate from week to week is comparatively slow for the first two weeks; for later weeks the growth rate is more rapid, agreeing with the result of ASMUNDSON & LERNER (1933).

TABLE 1. Average weights and average serum alkaline phosphatase activity at five weeks of age of chicks.

Week	0	1	2	3	4	5
Weight (g)	33.83 ±0.39*	47.75 ±0.93	85.82 ±2.53	140.49 ±3.97	222.68 ±5.52	296.87 ±7.11
Phosphatase activity**	—	—	—	—	—	18.39 ±0.60

* $\bar{x} \pm t_{.05} s_{\bar{x}}$.

** Expressed as millimole units.

Analyses of variance of the weights at each week are given in Table 2. Between sires, the mean squares for each week are all statistically insignificant, however, between dams within sires every one of the mean squares is highly significant.

TABLE 2. Analyses of variance of the weights at each week.

Source of variation	Degrees of freedom	Mean squares					
		0	1	2	3	4	5
Between sires	9	13.10	62.06	537.03	1279.8	2755.2	5207.1
Within sires							
Between dams	49	14.05**	57.16**	357.79**	754.3**	1670.0**	2656.7**
Between full-sibs	95	1.43	19.99	170.68	410.4	813.3	1344.0

** Significant at 0.01 level of probability.

That significance may be due to the fact that the weights of chicks are strongly affected by egg weights and egg qualities as the characteristics of dam at least during the first 5 weeks post hatch. This is also found in the change of heritabilily estimates of weights and the contributions of sires and dams to the estimates, as indicated in Figure 1. The heritability estimate at hatch was too high to be accepted. At one week of age, the estimate was still very high

at 0.85. The heritabilities of weights were constantly 0.58–0.67 at two weeks and later.

The heritability of body weight of fowl has been discussed by many investigators; the estimates mostly ranged 0.3–0.7. MATSUMOTO *et al.* (1958 *a*) estimated 0.53 at ten days of age, and 0.43 at 20 days. The heritability estimate at 8 weeks of age was 0.46 according to WYATT (1954), at 12 weeks of age was 0.50 (LERNER *et al.*, 1947), and 0.47 at maturity (GOODMAN & GODFREY, 1956). Considering the results of this present study and the reports of these workers, it seems that the heritability of weight will be constant at a value of about 0.5 from two or three weeks of age to maturity.

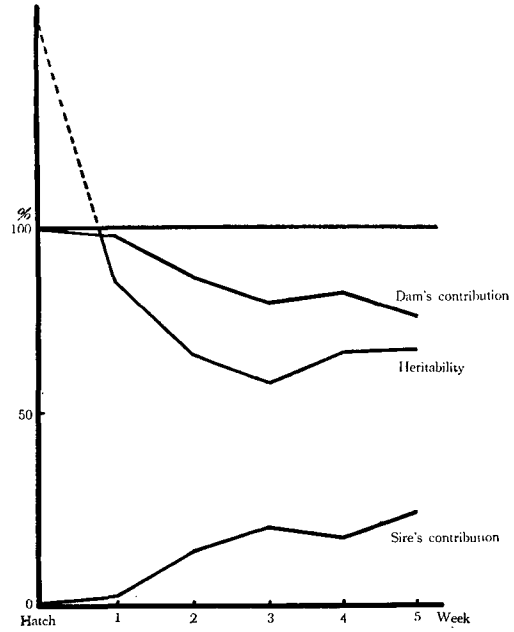

Fig. 1. Change of heritability of body weight, and the rate of sire's and dam's contribution to the heritability.

The estimate for hatch weight was completely determined by dam, the contribution of sire was zero. This result shows that the weight at hatch is completely determined by egg weight and egg quality as the characteristics of dam, and is not affected by sire. The contribution of dam at one week was still 98%. However, the contribution of sire increased gradually after two weeks of age, and at 5 weeks it was about 25%. Although it would be a matter of interest to investigate at which age the contributions of both sire and dam would balance, that matter was not studied in this paper. From this

fact mentioned above, it seems to be questionable whether to estimate the heritability of weight from variance component is adequate until the contributions of sire and dam on the weight become at least of equal value.

The analyses of variance and the heritability estimates of the serum alkaline phosphatase activity and the gain in the last 3 weeks are presented in Table 3. It is to be noted that significant difference between sires is observed for the gain in the last 3 weeks, while as for the weight, the sire's difference is insignificant at all weeks of age (see Table 2).

TABLE 3. Analyses of variance and the estimates of heritability of serum alkaline phosphatase and gain in last three weeks.

Source of variation	Degrees of freedom	Mean squares	
		alkaline phosphatase	gain
Between sires	9	81.65 **	3111.24 *
Within sires			
Between dams	49	13.29 *	1235.76 **
Between full-sibs	95	7.86	686.88
Heritability		0.849	0.657

* Significant at 0.05 level of probability.
** Significant at 0.01 level of probability.

This suggests that the genetical control of the sire over the growth is active as well as that of the dam, although the dam's intense influence through the egg bears upon the body weight itself at these stages of development.

In the serum alkaline phosphatase activity the difference between dams is significant, and between sires is highly significant, showing a trend opposite to weight and gain. This observation suggests that the physiological characteristics such as the levels of enzyme will not be affected maternally as seen for the body weight.

The heritability estimate of gain and alkaline phosphatase were 0.657 and 0.849, respectively. The heritability estimates of plasma alkaline phosphatase of fowl were reported by STUTTS *et al.* (1957). They estimated, in the mature male, the heritability of 0.35 from maternal half-sib correlation and 0.40 from paternal half-sib correlation, and in the female almost zero. The observation that the heritability of phosphatase activity in female was zero is of great interest agreeing with the results reported by PETERSON & PARRISH (1939 *a*) that the plasma phosphatase value in normal hens is greatly affected by egg-laying. In the male, however, 0.849 in this paper is greatly different from

0.35–0.40 estimated by STUTTS *et al.* This difference cannot yet be interpreted whether dependent on the difference of populations and age, or whether caused by random variation due to the comparative smallness of the number of experimental birds.

The correlation coefficient between the alkaline phosphatase activity and the weight at 5 weeks of age was −0.007, however, the correlation coefficient between the phosphatase activity and the gain in the final three weeks was 0.290. This correlation is statistically highly significant.

Correlation coefficient between alkaline phosphatase activity and gain in cattle reported by KUNKEL *et al.* (1953) was −0.56, significant at the 0.05 level of probability, and later a highly positive correlation in Brahman bulls was presented (KUNKEL *et al.*, 1954). FLETCHER *et al.* (1956) reported small positive correlations between serum alkaline phosphatase and subsequent gain in Brahman cattle. They showed also that the multiple correlations involving weight and age in addition to phosphatase and gain were higher than the single correlations, and statistically significant.

However, all these investigators did not study whether that the correlations were due to genetic correlations or environmental ones. Then, the phenotypic correlations were separated to genetic and environmental correlations (Table 4). Between alkaline phosphatase and weight, the environmental correlation is comparatively high with 0.562, while the genetic correlation is negative (−0.176). However, since the path coefficient from genotype to phenotype on both alkaline phosphatase and weight is very high (see Figure 2), the phenotypic correlation

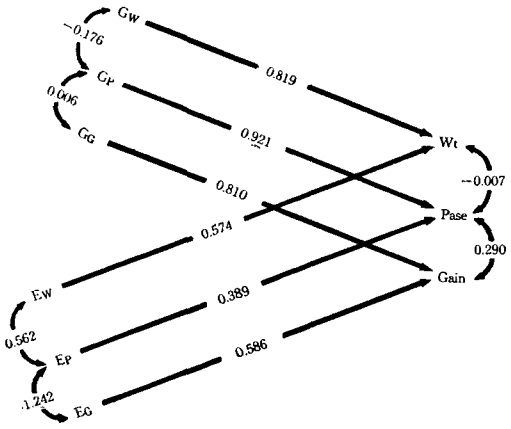

Fig. 2. The path coefficient diagram on serum alkaline phosphatase activity, body weight at 5th week, and gain in last 3 weeks.

TABLE 5. Correlation coefficients between serum alkaline phosphatase activity and body weight at 5 weeks age or gain in last three weeks.

Character correlated	Genetic	Environmental	Phenotypic
Phosphatase-weight	− 0.176	0.562	− 0.007
Phosphatase-gain	0.006	1.242*	0.290

* See text.

is negative though it is small. The genetic and environmental correlations between alkaline phosphatase and gain are both positive. The genetic correlation is only 0.006; the environmental one is 1.242 though it is theoretically an inadequate estimate because of over unit. Thus most of the phenotypic correlation between alkaline phosphatase and gain would depend on the environmental part. It is suggested by the result that the two characteristics may be correlated because some of the external and internal environmental influences affecting one also strongly affect the other, or the one affects the other as the environment of the other.

Summary

The birds used in this study were White Leghorn male chicks hatched in the spring of 1958. The serum alkaline phosphatase activity at the age of 5 weeks and the weights at each week were determined for a total of 154 chicks. A summary of results is as follows:

1. Analyses of variance for body weights showed that the differences between dams were highly significant, although between sires they were insignificant. The heritability estimates of weights were almost constant after two weeks of age, and the contribution of sire to the heritability increased gradually.

2. For the gain in the final 3 weeks, the difference between sires was significant, between dams was highly significant. The estimate of heritability was 0.657, agreeing with the heritability of weight.

3. For the serum alkaline phosphatase activity, the difference between sires was highly significant, between dams was significant. The heritability estimate was 0.849.

4. The correlation coefficient between the alkaline phosphatase and the weight at 5 weeks of age was almost zero, however, the correlation coefficient between the alkaline phosphatase and the gain in the last 3 weeks was 0.290, which was statistically highly significant. The genetic correlations were low in

both, while the environmental correlations were relatively high, that is, between the alkaline phosphatase and the weight it was 0.562, however, the coefficient between the alkaline phosphatase and the gain was inadequate because of over unit.

Acknowledgement

The authors wish to express their appreciation to Mr. M. YOSHIDA, Mr. S. TAKATSU and Mr. H. WATANABE, of the Takikawa Livestock Breeding Station, Takikawa, for supplying the birds used in this study.

References

ASMUNDSON, V. S. and I. M. LERNER (1933): Inheritance of rate of growth in domestic fowl. II. Genetic variation in growth of Leghorns. *Poult. Sci.*, **12** : 250–255.

AUCHINACHIE, D. W. and A. R. G. EMSLIE (1934): The significance of phosphatase estimations in the adult fowl. *Biochem. J.*, **28** : 1993–2001.

BESSEY, O. A., O. H. LOWRY and M. J. BROCK (1946): A method for the rapid determination of alkaline phosphatase with five cubic millimeters of serum. *J. Biol. Chem.*, **164** : 321–329.

FLETCHER, J. L., R. R. SHRODE and H. O. KUNKEL (1956): Serum alkaline phosphatase and gain in Brahman cattle. *J. Anim. Sci.*, **15** : 1119–1124.

GOODMAN, B. L. and G. F. GODFREY (1956): Heritability of body weight in the domestic fowl. *Poult. Sci.*, **35** : 50–53.

KUNKEL, H. O., M. F. FUTRELL and C. M. LYMAN (1954): Relationship of serum alkaline phosphatase activities to rates of gain in Brahman cattle. *Fed. Proc.*, **13** : 463–464.

————, D. K. STOKES, Jr., W. B. ANTHONY and M. F. FUTRELL (1953): Serum alkaline phosphatase activity in European and Brahman breeds of cattle and their crossbred types. *J. Anim. Sci.*, **12** : 765–770.

LERNER, I. M. (1950): *Population Genetics and Animal Improvement.* Univ. Press, Cambridge.

————, V. S. ASMUNDSON and D. M. CRUDEN (1947): The improvement of New Hampshire fryers. *Poult. Sci.*, **26** : 515–524.

MATSUMOTO, K., T. TONOUE and I. OKADA (1958 *a*): Heritability of physiological characters of chickens. I. On the relationship between the growth and the thyroid weight. *Memoi. Fac. Agr. Hokkaido Univ.*, **3** : (1), 130–134.

————, ———— and ———— (1958 *b*): Heritability of physiological characters of chickens. II. The hemoglobin and reduced glutathione level in blood. *Memoi. Fac. Agr. Hokkaido Univ.*, **3** : (1), 135–139.

PETERSON, W. J. and D. B. PARRISH (1939 *a*): Fluctuations of phosphatase and inorganic phosphorus in the blood of the laying hen during the period of egg formation. *Poult. Sci.*, **18** : 54–58.

PETERSON, W. J. and D. B. PARRISH (1939 *b*): Phosphatase and inorganic phosphorus in the plasma and whole blood of the fowl. *Poult. Sci.*, **18** : 59–62.

SNEDECOR, G. W. (1948): *Statistical Methods.* 4th Edit. Iowa State College Press, Ames, Iowa.

STUTTS, E. C., W. E. BRILES and H. O. KUNKEL (1957): Plasma alkaline phosphatase activity in mature inbred chickens. *Poult. Sci.*, **36** : 269–276.

WYATT, A. J. (1954): Genetic variation and covariation in egg production and other economic traits in chickens. *Poult. Sci.*, **33** : 1266–1274.