Proc. 3rd All Africa Conf. Anim. Agric. & 11th Conf. Egyptian Soc. Anim. Prod., Alexandria, Egypt, 6-9 November 2000: 535-542

IMPACT OF SELECTION FOR BODY WEIGHT AND HUMORAL IMMUNE RESPONSE OF PARENT STOCK ON IMMUNOLOGICAL STATUS OF BROILER CHICKS

A.M. Atta, A.M. Abdou and H.B. Gharib

Animal Production Department, Faculty of Agriculture, Cairo University,Giza, Egypt

SUMMARY

Arbor Acres broiler breeder sires were divergently selected for 8-wk. body weight (HW , LW) , whereas dams were divergently selected for 32-wk antibody response (HT ,LT) against sheep red blood cells (SRBC) , Sire mating with dam was carried out in a 2×2 Factorial design . The humoral antibody titer against Newcastle disease virus (NDV) and SRBC , in vivo cell mediated immune response [cutaneous basophil hypersensitivity (CBH)] , and body weight were detected in progeny chicks . Progeny of HW sire harvested significantly higher antibody response against NDV at 4 and 6 weeks of age than those of LW sire, and was also higher at 2 and 7 weeks of age but not significantly differences. Neither selection criterion of sire nor dam affected 7 wk- old antibody response against SRBC of progeny. CBH of HT progeny was significantly superior over that of LT chicks; On the other hand sire selection criterion did not influenced CBH of progeny .At 7-wk body weight of HW progeny was significantly heavier than those counterpart of LW chicks.

Estimates of sire h^2 for NDV antibody titer and body weight ranged from 0.273 to 0.563 and from 0.358 to 0.633 resp., while it was 0.449 for anti-SRBC antibody titer. There were positive phenotypic and genetic correlation for body weight with NDV antibody titer versus negative ones with SRBC antibody titer.

Keywords: Broiler strain, selection for antibody titer, cell mediated, body weight, heritability, correlation

INTRODUCTION

The commercial broiler of today appears to have compromised humoral and cell mediated immunecompetance, which is manifestsed in poor antibody production to SRBC, lower resistance to NDV and *Pasteurella multocida* and higher mortality (Han and Smyth, 1972, 1973; Mauldin *et al.*, 1978; Qureshi and Havenstien, 1994, Nestor *et al.*, 1996 a, b) lower mitogenic response to concanavalin A. (Li *et al.*, 1998, 1999) ,and change in T lymphocyte subpopulation (Li *et al.*, 2000). Such correlated responses have been attributed to the intense selection for rapid growth to market weight. Boa-Amponsem *et al.*(1999) suggested that demands for fast growth, whether genetically induced or imposed by nutritional manipulations, results in deprivation of resources to systems that determine general fitness Conversely chickens selected for high antibody production to SRBC have been associated with lower body weight (Siegal and Gross, 1980; Siegal *et al.*, 1982; Martin *et al.*, 1990;Parmentier *et al.*, 1998) greater resistance to some infectious diseases (e.g., Mark's, Newcastle disease and *Eimeria tenella*) than a line selected in the opposite direction (Gross *et al.*, 1980; Dunnington *et al.*, 1986, 1992).

The purpose of this study was to compare the humoral ; cell mediated immune response and body weight of broiler chicks produced from sire divergently selected for 8-week body weight and dam divergently selected for 32-weeks antibody titer against SRBC. Furthermore, heritability of antibody titer against NDV and SRBC antigens and body weight were estimated as well as phenotypic and genetic correlation among these traits .

MATERALS AND METHODS

Arbor Acres broiler breeder commercial strain was used in this study and maintained during the entire life period in a curtain sided naturally ventilated house. At 8-wk of age 200 males were weighted to nearest grams and the heaviest 25% male (HW) represented the first group, whereas the lightest 25% male (LW) represented the second group. However, the selection criterion of dam (1000dam) was the total antibody titer against sheep red blood cells (SRBC) 7day postimmunization with 1 ml of 10% SRBC suspension at 32 weeks of age. The highest 25% dam (HT) represented the first group while the

lowest 25% dam (LT) represented the second group. At 33 weeks of age, 8 males from each group mated 64 dam from each group in 2×2 factorial design using 32 individual sire breeding pens.
Eggs were collected daily for 10 days, cracked, dirty, misshapen or extreme size were culled and removed, whereas hatched eggs were fumigated, and then, set in a forced air incubator that provided 37.5°C and 60% RH in setter and 36.9°C and 80% RH in hatcher . At hatch, 25 chicks from each sire pen were randomly chosen, wing banded weighed to nearest grams and placed in litter floor pens at density of 10 birds / m^3 using wood shaving as a litter over concrete floors. All chicks were vaccinated against Newcastle disease (NDV) at 6 and 18 days of age using B1 and lasota strain vaccine, respectively. Infection bursal disease (IBD) vaccine was administrated at 9 days of age. Drinking water was administrated with live vaccine. At 10 days of age 0.5 ml bivalent emulsion inactivated NDV and IBD vaccine was injected subcutaneous in the back of the neck. All chicks were exposed to continuous light (24 L: 0D) during the first three days of age and then received 23 L: 1D. During the first 4 weeks of age, the chicks were fed a commercial starter ration (3000-3100 Kcal. ME/Kg and 23% crude protein) and then fed a commercial finisher ration (3300-3400 Kcl ME/KG and 20% crude protein). Both feed and water were provided with *ad libitum* consumption. Body weight was recorded at 2,4,6 and 7 weeks of age.

Antibody titer against NDV

Blood sample were collected from ten chicks of each mating just after hatch (to detecat maternal antibody titer) and at 2, 4, 6 and 7 weeks of age, antibody titer against NDV was measured by hemagglutination inhibition (HI) test as described by Beard (1980).

Sheep red blood cells challenge

The SRBC were collected and washed three timed in normal saline. After final wash, the packed cells were brought to a 10% vol/vol solution in the 9% Nacl solution. At 6 weeks of age ten chicks from each mating were injected i.v. in the wing vein with 1 ml of 10% SRBC solution to induce a T cell dependent antibody response. Blood samples were drawn at 7 days postinjection, serum was recovered from clotted blood by centrifugation at 4000 rpm. Antibody titer against SRBC were measured using the microtiter procedure of Van der Zijpp and Leanstra (1980). Titers were expressed as the log 2 of the reciprocal of highest dilution giving complete agglutination.

Cutaneous basophil hypersensitivity (CBH) responses

Ten males from each line were randomly chosen at 6-weeks of age. CBH response was determined by injecting 0.1 ml of phytohemagglutinin-p (PHA-P) (100μ g/ml) intradermally into a defined area on the right wattle, whereas saline (0.1 ml) was ingected in the left wattle and served as a control. The thickness of both wattles at 24 hrs after injection were measured in mm using a micrometer. The CBH response was calculated as a relative response [thickness of right wattle (PHA-P) response) ÷ thickness of left wattle (saline response)].

Statistical analysis

Data were subjected to two-way analysis of variance in a factorial arrangement. General linear model (GLM) adapted to micro computer of statistical analysis system (SAS) software package (1989). The statistical model was

$Yijk = \mu + Bi + Aj + (BA)ij + Eijk$

Where

μ = the overall mean.

Bi = the effect of the i^{th} body weight group

Aj = the effect of the j^{th} SRBC antibody titer group

(BA)ij = the effect of interaction between i^{th} and j^{th}.

Eijk = the observation of k^{th} individual at the j^{th} SRBC antibody titer under the i^{th} body weight group.

Duncan new multiple range test was used for the comparison between means (Duncan, 1955)
The heritability was calculated from the sire component of variance as :

$h^2s = 4ó^2s / ó^2t$

where:

^2s = the effect of sire component of variance.

^2t = the effect of the total phenotypic variance.

Phenotypic and genetic correlation among SRBC and NDV antibody titer and body weight were calculated from half-sib correlation as reported previously (Becker, 1985).

RESULTS

Body weight

The results in Table 1 show that HW × HT mating produced significantly ($p \leq 0.05$) heaviest broiler chicks at 7 weeks of age when compared to those produced from LW × LT mating . However, no differences were found before this age. This superiority attributed to sire , so broiler chicks produced from HW sire had superior body weight by about 15.8, 3.9, 107.3 and 186.8 gms than those produced from LW sire at 2, 4, 6 and 7 weeks of age respectively , however, significant ($p \leq 0.05$) difference was only observed at only 7 weeks of age. On the other hand selected dam for antibody titer against SRBC did not influenced the body weight of progeny at any age .

Table 1. Influence of selection criterion of parent on body weight (gm) of broiler chicks

Parent Sire	Dam	Age (wks)			
		2	4	6	7
Interaction means (Mating)					
HW	HT	350±10	1069±33	2020±69	2498±72
	LT	349±9	1071±28	1991±59	2445±66
LW	HT	335±10	1068±33	1888±69	2321±79
	LT	332±9	1065±28	1903±59	2260±62
Pooled means					
HW		349±6	1070±21	2004±44	2469±54^{A}
LW		333±6	1066±21	1896±44	2283±54^{B}
	HT	342±7	1068±23	1954±44	2418±59
	LT	341±6	1068±20	1947±42	2346±59

^{ab} interaction means within column with different letter are significantly different ($p \leq 0.05$)

^{AB} pooled mean within column within each parent with different letter are significantly different ($p \leq 0.05$).

Antibody titer

Table 2 shows antibody titer against NDV of progeny produced from each mating just after hatch till 7 weeks of age. Progeny of HW × HT mating harvested significantly ($p \leq 0.05$) higher titer at 4 and 6 weeks of age than of both of LW × LT and LWxHT mating whereas those produced from HW × LT mating occupied intermediate with no significant with other group. Also the same pattern was showed in the overall mean of antibody titer against NDV, selected sire for 8 weeks body weight influenced the HI titer (Table 2), where the progeny produced from HW sir had higher pool titer through the entire experimental period compared with those produced from LW sire , these differences were significant ($p \leq 0.05$) at 4 and 6 weeks of age. On the other hand , the selection criterion of dam did not influence antibody titer against NDV.

Table 2. Influence of selection criterion of parent on antibody titer against NDV of broiler chicks

Parent Sire	Dam	Age (wks) 0*	2	4	6	7
Interaction means						
(Mating)						
HW	HT	4.6±0.2	5.6±0.18	6.1±0.3^{a}	6.9±0.2^{a}	7.0±0.3
	LT	4.4±0.2	5.8±0.18	5.5±0.3^{ab}	6.3±0.2^{ab}	7.0±0.3
LW	HT	4.3±0.2	5.5±0.18	4.8±0.3^{bc}	6.0±0.2^{b}	7.0±0.3
	LT	4.4±0.2	5.4±0.18	4.6±0.3^{bc}	5.8±0.2^{b}	6.5±0.3
Pooled means						
HW		4.5±0.18	5.7±0.14	5.7±0.2^{A}	6.5±0.19^{A}	7.0±0.2
LW		4.4±0.18	5.4±0.14	4.7±0.2^{B}	5.9±0.19^{B}	6.7±0.2
	HT	4.5±0.2	5.5±0.16	5.4±0.3	6.5±0.21	7.0±0.26
	LT	4.4±0.2	5.6±0.14	5.1±0.2	6.1±0.18	6.8±0.23

*Just after hatch (maternal titer)

^{ab} interaction means within column with different letter are significantly different ($p \leq 0.05$)

^{AB} pooled mean within column within each parent with different letter are significantly different ($p \leq 0.05$).

The results in Table 3 also show that neither sire nor dam selection criterion influence antibody titer against SRBC at 7 weeks of age.

Table 3. Influence of selection criterion of parent on anti-SRBC antibody titer and CBH value of 7-wks-old broiler chicks

Parent Sire	Dam	SRBC	CBH
Interaction means			
(Mating)			
HW	HT	6.0±0.95	1.76±0.17^{ab}
	LT	5.38±0.67	1.58±0.14^{ab}
LW	HT	5.7±0.81	1.82±0.17^{a}
	LT	5.0±0.67	1.39±0.15^{b}
Pooled means			
HW		5.58±0.54	1.65±0.11
LW		5.29±0.54	1.58±0.11
	HT	5.83±0.61	1.79±0.12^{A}
	LT	5.18±0.61	1.56±0.12^{B}

^{ab} means within column with different letter are significantly different ($p \leq 0.05$)

^{AB} pooled mean within column within each parent with different letter are significantly differ ($p \leq 0.05$).

CBH response

The results of CBH response showed that selected sire for 8-weeks body weight did not influenced cell mediated immune response that detected by CBH response Table 3. However, broiler chicks produced from HT dam had significant ($p \leq 0.05$) higher CBH value than those produced from LT dam.

Sire heritabilities

Regardless of line, sire heritabilities estimated of NDV and SRBC antibody titer and body weight are given in Table 4. The h^2 for NDV antibody titer were at low and moderate magnitude. It was 0.353 at 2 weeks of age, then increased to 0.563 at 4 weeks, after that decreased gradually to the lower one at 7 weeks (0.273), while the h^2 of body weight were ranging from 0.358 to 0.633. The sire h^2 of SRBC antibody titer at 7 weeks of age was 0.449.

Table 4. Estimates of sire heritabilities and phenotypic and genetic correlations for body weight and NDV and SRBC antibody titer in broiler chicks

Traits	ND2	WK2	ND4	WK4	ND6	WK6	ND7	WK7
ND2	0.353	-0.03	0.05	0.06	0.16	0.09	-0.05	0.14
WK2	@	0.633	0.10	0.80**	0.09	0.67**	0.27**	0.59**
ND4		0.74	0.563	0.07	0.35**	0.23*	0.24*	0.29**
WK4	@		0.67	0.457	0.17	0.81**	0.34**	0.77**
ND6		0.30		0.55	0.489	0.06	0.30**	0.15
WK6	0.49		@		0.72	0.358	0.29**	0.93**
ND7		0.84		@		@	0.273	0.30**
WK7	0.37		@		0.83		0.84	0.418

Traits	ND7	SRBC7	WK7
ND7		0.02	
SRBC7	-0.73	0.449	-0.11
WK7		-0.222	

Above diagonal phenotypic correlation
Below diagonal genetic correlation
On diagonal h^2 estimates
* Significant phenotypic correlation ($p \leq 0.05$)
** High significant phenotypic correlation ($p \leq 0.01$)
@ Imaginary values 20

Phenotypic and genetic correlation

Table 4 presents that the phenotypic and genetic correlation among NDV and SRBC antibody titer and body weight at 2, 4, 6 and 7 weeks of age. Regardless of line, the phenotypic and genetic correlation for NDV antibody titer with body weight at most ages were positive and significant ($p \leq 0.05$). The genetic correlation was consistently greater than phenotypic correlation. The positive and significant phenotypic correlation between body weight and NDV antibody titer ranged from 0.23 to 0.34, while genetic correlation were ranging between 0.30 and 0.84. The phenotypic correlation for SRBC antibody titer with body weight at 7 weeks of age was negative and at low magnitude (-0.11) as well as genetic correlation (-0.222).

DISCUSSION

This study was carried out in an attempt to improve the performance of broiler chicks through genetic selection of broiler breeder stock for body weight and humoral antibody response.

The current study showed that selected sire for 8-weeks body weight improved growth and body weight of progeny. Several authors have been reported that selection for 8-weeks body weight resulted in highly significant increase body weight of progeny, which concomitant with rapid growth rate and improvement of feed convrision (Liu *et al.*, 1994; Marks, 1995). Furthermore, selection for increased immune responsiveness may make permanent improvements in fitness, enhance vaccine effectiveness and finally decreasing the losses in production efficiency due to disease presence. Selection based upon antibody response to SRBC in the present study was underlying the assumption of Lamont, (1994) that response to this complex, nonpathogenic T-cell dependent antigen should be a broad indicator of general immunocompetance. This assumption was established by Gross *et al.* (1980) and Parmentier *et al.* (1996) who found positive associations between anti-SRBC antibody and resistance to NDV. Althought, previous reports showed that selection for high juvenile body weight associated with decrease in humoral response against NDV (Mauldin *et al.*, 1978; Qureshi and Havenstein, 1994; Praharaj *et al.*, 1995). These findings are in contradiction with the present result which exhibited a positive relationship between body weight and anti-NDV antibody level at 4 and 6 weeks of age, and also with results of Tsai *et al.* (1992) that antibody titer detected with a hemaglutination inhibition test were higher in surviving selected turkey line for body weight (F) than those of random breed line in a challenge experiment with NDV. However, Nester *et al.* (1996 a,b)showed that this line was more suseptible to NDV, and thy interpreted this phenomena that other mechanisms such as cell mediated immunity may be contributing to the explanation of the susceptibility of the F line. Li *et al.* (2000) explained that the body weight selection resulted in change in T lymphocyte subpopulation, Thus F line have a higher percentage of $CD4^+$ $CD8^-$ T cell (helper cells) that gives assistance to both T and B cells

in initiating the immune response, and under influence of certain kinds of cytokines or hormones beneficial to the growth, may secrete some cytokines that may favorabl activate B cell differentiation to produce higher antibody titer but inhibits the cytotoxic T cell activity or activate the suppressor T cells at the same time.The absence of the significant differences on maternal antibody transmitted against NDV between progeny indicates that selected dam for antibody titer against SRBC did not change the transmission of antibody from hen to their progeny.This finding does not agree with those of Boa-Amponsen *et al.* (1997b); Ning *et al.* (1999) that increased immunity in adult hens is important for their resistance to virus diseases and important for the protection of chicks through the transmission of maternal antibody because maturation of neonatal immune system is not complete during the early posthatch period.

CBH or Delayed hyper sensitivity in response to plant lactins is conventionally used to measured *in vivo* the cell mediated immunity in birds (Bachman and Mashaly, 1987). The PHA-P lactin stimulates T lymphocyte by indirectly cross linking the T cell receptor complex. Cell mediated immunity plays a major role in the responses against intracellular bacteria and viruses (Abbas *et al.*, 1994). The current experiment indicates that selected dam for high anti-SRBC antibody improved the cell mediated immunity that was measured by CBH method in progeny. Parmentier *et al.* (1994) reported that selected line for high antibody titer against SRBC had higher CBH value than a line in the opposite direction. On the other hand selection criterion of dam did not influence antibody titer against NDV and SRBC and also body weight of progeny. This may be due to the repetition of selection that had happened for only one generation. Lamont (1994) explained that improving immune response via genetic selection is a desirable approach for many reasons. Although the progress per generation may be small, but it is heritable and therefore commulative over generations.

During the experimental period, the h^2 trend of NDV antibody titer indicated that it was varying with age, it was at the peak at 4 weeks of age then decreased at latter age. The h^2 estimates were in agreement with those estimated by Peleg *et al.* (1976). They found that the h^2 was 0.31 and 0.60 from sire variance components for NDV antibody titer in two line of White Rock chicken, and Soller *et al.* (1981) estimated it as 0.41.

The moderated heritability of body weight in this study is in partial agreement with those (0.27 to 0.431) estimated at ages 2 to 6 weeks that were reported by Bou-Amponsem *et al.*(1998). Furthermore Kinny (1969) summarized the h^2 of body weight at different ages and were found to range from 0.30 to 0.78. Moreover, Marks (1980) reported that h^2 of body weight at 6 weeks of age ranged from 0.37 to 0.41.

In the present study, the sire h^2 of SRBC antibody titer (0.23 and 0.25) was higher than those reported by Martin *et al.* (1990) in high and low SRBC antibody titer chicken lines. Ahmed (2000) estimated the sire h^2 as (0.340) in non selected chicken, but lower than that (0.52) obtained after four generations of selection for SRBC antibody titer in chicken (Van der Zijpp *et al.*, 1987).

The low phenotypic correlation versus the moderate to high genetic correlation indicated a masking of the genetic potential by the environment. The positive phenotypic and genetic correlation between NDV antibody titer and body weight indicate that selection for body weight may increase the antibody titer against NDV, this suggestion in complete agreement with the results of Tsai *et al.* (1992) and Sacco *et al.* (1994). They reported that HI titers to NDV challenge were significantly higher in a line of Turkey selected for increased 16 week body weight than in its random bred control line.

The direction of change and the magnitude of phenotypic and genetic correlation between SRBC antibody titer and body weight were correspondent to those observed in lines of chickens selected for respons to SRBC by Dunnington and Siegel (1984); Van der Zijpp *et al.* (1983 and 1988) Martin *et al.* (1990) and Ahmed (2000).

In conclusion, the results reported here would imply the importance of selection criterion of sire (8-wk – body weight) and dam (32-wk antibody titer against SRBC) to improve broiler performance which include 7-wk body weight, humoral antibody titer against NDV and cell mediated immune response.

REFERENCES

Abbas, A. K., A. H. Lichtman, and J. S. Pober. 1994. Cellular and Molecular Immunology. 2nd ed. W. B. Saunderns Co., Philadelphia, PA.

Ahmed, A.S., 2000 . Divergent selection for high and low antibody titer against sheep red blood cells (SRBC) in laying chickens. Ms.C. thesis, faculty of agriculture, Cairo university.

Bachman. S.E., M. Mashaly, 1987. Relationship between circulatiog thyroid hormones and cell-Mediated immunity in immature male chickens. Develop and Comp Immun, 11: 203-213.

Beard, C.W., 1980. Serologic procedures page 129-135. *Isolation and Identification of Avian Pathgens.* B. hitchner, C.H. Domernuth, H.G. Purchase and Williams, ed Am. Assoc. Avian pathol. Inc. Endwell, NY, USA.

Becker, W.A., 1985. Manual of quantitative genetics. Academic Enterprises. Pullman W.A.

Boa-Amponsem, K., E.A. Dunnington, and P.B. Siegal, 1997a. Genetic architecture of antibody responses of chickens to sheep red blood cells. J. Anim. Breed. Genet. 114: 443-449

Boa-Amponsem, K., E.A. Dunnington, and P.B. Siegal, 1997b. Antibody transmitting ability of hens from lines of chickens differing in response to SRBC antigen. Br. Poult. Sci. 38: 480-484.

Boa-Amponsem, K., E.A. Dunnington, K.S. Baker, and P.B. Siegal, 1998. Diet and humoral responsivensess of lines of chickens divergently selected for antibody response to sheep red blood cells. Arian Dis. 42

Boa-Amponsem, K., E.A. Dunnington, K.S. Baker, and P.B. Siegal, 1999. Diet and immunological memory of lines of white leghorn chickens divergently selected for antibody response to sheep red blood cells. Poultry Sci. 78: 165-170.

Duncan, D.B., 1955. Multiple range and multiple F test. Biometrics. 11:1-42

Dunnington, E.A. and P.B. Siegal, 1984. Age and body weight at sexual maturity in femal white leghorn chickens. Poultry Sci. 63: 828-830.

Dunnington, E.A., A. Martin, W.E. Briles, R.W. Briles and P.B. Siegal, 1986. Resistance to Marek's disease in chickens selected for high and low antibody responses to sheep red blood cells. Arch. Geflügelkd. 50: 94-96.

Dunnington, E.A., W.B. Gross, A. Martin, and P.B. Siegal, 1992. Response to *Eimeria tenella* of chickens selected for high or low antibody response and differing in haplotypes at the major histocompatibility complex. Avian Dis. 36: 49-53.

Gross, W.B., P.B. Siegal, R.W. Hall, C.H. Domermuth, and R.T. DuBoise, 1980. Production and persistence of antibody in chicken to sheep erthrocytes. 2. Resistance to infectious diseases. Poultry Sci. 59: 205-210.

Han, P.F.S., and J.R. Smyth, Jr., 1972. The influence of growth rate on the development of Marek's disease in chickens. Poultry Sci. 51: 975-985.

Han, P.F.S., and J.R. Smyth, Jr., 1973. The influence of maternal effect on the response of fast and slow growing chickens to a Marek's disease virus. Poultry Sci., 52: 909-915.

Kinney, T.B., 1969. A summary of reported estimates of heritabilities and of genetic and phenotypic correlations for trials of checks. US Departement of Agriculture Handbook Number 363. Agric. Res. Serv., US Dept. Agric., Washington, DC.

Lamont, S.J., 1994. Poultry immunogenetics: which way do we go?. Poultry Sci. 73: 1044-1048.

Li, Z., K.E. Nestor, and Y.M. Saif, 1998. Effect of selection for increased body weight in turkeys on T lymphocyte subpopulations and mitogenic responses. Poultry Sci. 77 (Suppl. 1): 152. (Abstr.).

Li, Z., K.E. Nestor, and Y.M. Saif, S. Fan, M. Luhtala, and O. Vainio, 1999. Cross-reactive anti-chicken CD4 and CD8 monoclonal antibodies suggest polymorphism of the turkey CD8α molcule. Poultry Sci. 78: 1526-1531.

Li, Z., K.E. Nestor, Y.M. Saif, and M. Luhtala, 2000. Flow cytometic analysis of T lymphocyte subpopulations in large-bodied turkey lines and a randombred control population. Poultry Sci. 79: 219-223.

Liu, G., E.A.Dunnington and P.B.Siegal, 1994. Responses to long term divergent selection for eight-week body weight in chickens. Poultry Sci. 73: 1642-1650.

Markes, H.L., 1995. Selection for high eight-week body weight in Normal and Dwarf chickens under high-protein and high energy Diets. Poultry Sci. 74: 593-600.

Marks, H.L., 1980. Influence of dietary energy on heritability of 6-and 8-week body weight. Poultry. Sci. 59: 173-176.

Martin, A., E.A. Dunnington, W.B. Gross, W.E. Briles, R.W. Briles, and P.B. Siegal, 1990. Production trails and alloantigen systems in lines of chickens selected for high and low antibody responses to sheep erythrocytes. Poultry Sci. 69: 871-878.

Mauldin, J.M., P.B. Siegal, and W.B. Gross, 1978. Dwarfism in diverse genetic backgrounds. 2. Behaviour and disease resistance. Poultry Sci. 57: 1488-1492.

Nestor, E., D.O. Noble, J. Zhu, and Y. Moritsu, 1996a. Direct and correlated responses to long-term selection for increased body weight and egg production in turkys, Poultry Sci. 75: 1180-1191.

Nestor, E., D.O. Noble, J. Zhu, and Y. Moritsu, 1996b. Research note: Influence of growth selection in turkeys on resistance to *Pasteurella multocida*. Poultry Sci. 75: 1161-1163.

Ning Yang, E.A. Dunnington, and P.B. Siegal, 1999. Kinetics of antibody responses in hens from chicken lines divergently selected for response to sheep blood cells. Poultry Sci. 78: 1081-1084.

Parmentier, H.K., M. Walraven, and M.G.B. Nieuwland, 1998. Antibody responses and body weights of chicken lines selected for high and low humoral responsiveness to sheep red blood cells. 1. Effect of *Escherichia coli* lipopolysaccharide. Poultry Sci. 77: 248-255.

Parmentier, H.K.; Siemonsma, R. and Niewland, M.G.B., 1994. Immune responses to bovine serum albumin in chicken lines divergently selected for antibody response to sheep red blood cells. Poultry Sci. 73: 825-835.

Peleg, B.A.,A.M. soller, N. ron, K. Hornstein, T. brody, and E. kalmer, 1976. Familial differences in antibody response of broiler chickens to vaccination with attenuated and inactivated newcastle disease virus vaccine. Avian dis. 20:661-668.

Praharaj, N.K.; E.A. Dunnington and P.B. Siegal, 1995. Growth, immunoresponsiveness and disease resistance of divers stocks of chickens reared under two nutritional regimens. Poultry Sci. 74: 1721-1729.

Qureshi, M.A., and G.B. Havenstein, 1994. A comparison of the immune performance of a 1991 commercial broiler with a 1957 randombred strain when fed "typical" 1957 and 1991 broiler diets. Poultry Sci. 73: 1805-1812.

Sacco, R.E., K.E. Nestor, Y.M. Saif, H.J. Tsai, and R.A. Patterson, 1994. Effect of genetic selection for increased body weight and sex of poult on antibody response of turkeys to Newcastle disease virus and multocida vaccines. Avian Dis. 38: 33-36.

SAS, 1989. SAS / STAT User's Guide. SAS Institute Inc., Cary, NC.USA.

Siegal, P.B. and W.B. Gross, 1980.Production and persistence of antibody in chicken to sheep erythrocytes. 1. Directional selection. Poultry Sci. 59: 1-5.

Siegal, P.B. and W.B. Gross, and J.A. Cherry, 1982.Correlated responses of chickens to selection for production of antibody in chicken to sheep erythrocytes. Anim. Blood Groups Biochem. Genet. 13: 291-297.

Soller, M., D. Heller, B. peleg, and k. Hornastein, 1981. Genetic and phenotypic correlation between immune response to *Escherishia coli* and to newcastle disease virus vaccine. Poultry Sci. 60:49-53.

Tsai, H.J., Y.M. Saif, K.E. Nestor, D.A. Emmerson, and R.A. Patterson, 1992. Genetic variation in resistance of turkeys to experimental infection with Newcastle disease virus. Avian Dis. 36: 561-565.

Van der Zijpp, A.J. and F.R. Leenstra, 1980. Genetic analysis of the humoral immune response of white leghorn chicks. Poultry Sci. 59: 1363-1369.

Van der Zijpp, A.J., J.J. Blankert, E. Egberts and M.G.J. Tilanus, 1988. Advances in genetic disease resistance in poultry. pages 131-138 in: Advances in Animal Breeding. Pudoc Wageningen, Wageningen, The Netherlands.

Van der Zijpp, A.J., K. Frankena, J. Boneschanscher and M.G.B. Nieuwaland, 1983. Genetic analysis of primary and secondary immune responses in the chicken. Poultry Sci. 62: 565-572.

Van der Zijpp, A.J., M.B. Kreukniet and M.G.B Nieuwland, 1987. Responses to selection for high and low antibody production. Poult. Sci. 66: 188 (Abstr).