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Glutathione peroxidase activity in different breeds and sexes of chickens during embryonic development up to peak of egg production

G.S. Farahat[1], E.A. Eissa[2], K. Balogh[3,4] and M. Mézes[4,5]

Fayoum University, Faculty of Agriculture,
[1]Department of Poultry Sciences,
[2]Department of Genetics
63514 Fayoum, Egypt
[3]University of Kaposvár, Research Group of Animal Breeding and Hygiene,
Faculty of Animal Science
H-7400 Kaposvár, Hungary
[4]Szent István University,
Department of Nutrition, Faculty of Agricultural and Environmental Sciences
H-2103 Gödöllõ, Hungary

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ABSTRACT

Glutathione peroxidase (GSHPx) activity was investigated in the liver, red blood cells (RBC) and blood plasma (BP) of different chicken genotypes. Significant differences among genotypes and age groups were found in liver GSHPx activity during embryonic development and in day-old chickens. Breed, sex and age effects were found in RBC and BP from one day of age until peak egg production. A negative correlation was found between embryo liver GSHPx activity and egg weight (-0.24; $P \leq 0.01$), between RBC and BP GSHPx activity and body weight (-0.32 and -0.44; $P \leq 0.01$), and between liver and RBC GSHPx activity (-0.54; $P \leq 0.01$), while positive correlations were demonstrated between liver and BP (0.66; $P \leq 0.01$) and BP and RBC (0.32; $P \leq 0.01$) GSHPx activity. In conclusion, variation in GSHPx activities in different chicken breeds during development suggests that it is genetically regulated. This finding indicates that GSHPx activity may be useful in selection.

KEY WORDS: chicken, embryo, glutathione peroxidase, breed, sex

[5] Corresponding author: e-mail: Mezes.Miklos@mkk.szie.hu

INTRODUCTION

Different reactions are required for the maintenance of metabolism and energy production in the cell, during which potentially toxic oxygen free radicals are also produced (Chester and Arthur, 1988). The body is protected against reactive oxygen metabolites by the biological antioxidant defence system, which includes antioxidant enzymes and low molecular weight antioxidants (Surai, 2002). It has been suggested that the cellular first line of antioxidant defence is based on the activity of three types of enzymes: superoxide dismutases, glutathione peroxidases (GSHPx) and catalase.

Selenium-dependent GSHPx is a key intracellular antioxidant enzyme that contains a selenocysteine residue at its active site (Handy et al., 2006). Chicken embryo tissues are characterized by high concentrations of polyunsaturated fatty acids (Noble and Cocchi, 1990) and for that reason they are sensitive to lipid peroxidation (Gaál et al., 1995); protection against lipid peroxidation is, therefore, a crucial task for embryos. A genetic variation in GSHPx activity has been suspected previously in chickens (Cunningham et al., 1987; Shen et al., 1992; Shaaban et al., 2003, 2004). Correlation between the activity of GSHPx and body weight was shown to be significant, as well. Comparison among embryonic tissues showed that the highest GSHPx activity at all stages of development was in the liver, and increased throughout embryonic development, reaching its maximum at the time of hatching (Gaál et al., 1995). Several studies have suggested that activities of GSHPx in different tissues are affected by sex. This may be the result of differences in distribution of selenium in males and females, or of metabolic differences (Finley and Kincaid, 1991). According to the free radical theory of ageing, it can be considered a process of irreversible changes associated with accumulation of free radicals induced by damage to the cell (Harman, 1956). There are also some observations about the correlation of GSHPx activity and production traits, such as body weight and weight gain in avian species (LaVronga and Combs, 1982).

The objectives of the present investigation were: a. determination of the phenotypic variation of GSHPx enzyme activity in the liver of chickens of different breeds during embryonic development up to the age of one day, b. estimation of the effects of breed, age and sex on GSHPx enzyme activity of red blood cell haemolysate (RBC) and blood plasma (BP) in different chicken breeds from the age of one day up to the age of peak egg production under standardized conditions, and c. estimation of the correlation between egg and body weight and GSHPx enzyme activity of liver, RBC and BP.

MATERIAL AND METHODS

Animals and experimental conditions

Four chicken breeds: White Plymouth Rock (WPR), Naked Neck Plymouth (NNP) and Naked Neck New Hampshire (NNNH) and Hungarian White (HW) used in this investigation are maintained at the Institute of Small Animal Breeding and Nutrition, Gödöllő (Hungary). All of the birds were clinically healthy and kept in the same environment and given the same diets with an average selenium content of 0.21 mg/kg. Fertilized eggs were incubated at 37.8°C and 60% relative humidity in a forced-draught incubator with automatic egg turning.

A total of 320 eggs (20 of each breed on each day of incubation) was weighed and the embryos were euthanized with cooling at -20°C for 5 min on the 14th, 16th, 18th and 20th day of incubation. Blood and liver samples were taken and processed for sex determination or immediately frozen (-20°C) until analysed.

A total of 720 blood samples (15 ♂ and 15 ♀ of each breed at each age) were collected on day one, and at 4, 8 and 12 weeks of age, at the age of sexual maturity (SM), laying of the first egg, and at peak egg production (highest egg production, HEP).

Egg weight (EW) and body weight (BW) were measured at the same time as the liver and blood samples were obtained.

Blood and liver samples

Blood samples were collected into tubes containing EDTA-Na_2 (0.2 mol/l) as an anticoagulant. Freshly collected blood samples were centrifuged at 2,500 rpm, plasma was removed and stored frozen (-20°C) until analysed. Erythrocytes were washed three times with a two-fold volume of physiological saline (0.65% w/v NaCl), then haemolysed with nine-fold of their volume of redistilled water and by freezing (-20°C, 18 h) and thawing (37°C, 30 min). Liver samples were homogenized before analysis with a nine-fold amount of physiological saline and the 10,000 *g* supernatant fraction was used for determination of enzyme activity.

Biochemical methods

GSHPx activity was measured using reduced glutathione and cumene-hydroperoxide as co-substrates (Lawrence and Burk, 1976) and the oxidation of reduced glutathione measured by the method of Sedlak and Lindsay (1968). Enzyme activity was expressed in units reflecting the oxidation of reduced glutathione in nm per min at 25°C and was related to protein content. The total protein

content of BP and RBC was determined using the biuret method (Weichselbaum, 1946), while that of liver homogenate, using the Folin phenol reagent (Lowry et al., 1951). Sex determination was made in embryonic blood samples. DNA was extracted from blood samples following haemolysis and protein digestion using the salting out method. Approximately 80-100 ng DNA were taken for PCR using Dynazyme® DNA polymerase (Finnzymes, Oy, Finland) and the appropriate buffer in a total volume of 15 μl. A total of 26 RAPD primers of AP Biotech and Operon were tested for variable fragments. The RAPD-PCR protocol (Williams et al., 1990) was carried out in a 9700 GeneAmp thermocycler 4 min 95°C denaturation followed by 45 cycles of 15 sec at 95°C, 1 min at 36°C and 1 min at 72°C extension. PCR products were separated on 1.5% agarose gel with ethidium-bromide.

Statistical analysis

Data of liver, BP and RBC GSHPx activity were subjected to analysis using three-way ANOVA with breed, age and sex as the main effects, according to the following unitrait model:

$$Y_{ijkl} = \mu+G_i+A_j+S_k+(GA)_{ij}+(GS)_{ik}+(AS)_{jk}+(GAS)_{ijk}+e_{ijkl}$$

where: μ - common mean; G_i - effect of the i^{th} breed; A_j - effect of the j^{th} age; S_k - effect of the k^{th} sex; $(GA)_{ij}$ - effect of interaction of the i^{th} breed with the j^{th} age; $(GS)_{ik}$ - effect of interaction of the i^{th} breed with the k^{th} sex; $(AS)_{jk}$ - effect of interaction of the j^{th} age with k^{th} sex; $(GAS)_{ijk}$ - effect of interaction of the i^{th} breed with the j^{th} age with the k^{th} sex; e_{ijkl} - random error term, using the GLM procedure of SPSS program (SPSS for Windows, 1999).

Means were compared for main effects and their interaction by Duncan's multiple range test (Duncan, 1955), when significant F values were obtained ($P<0.05$). Correlation analyses were performed by using the CORR procedure from SPSS (SPSS for Windows, 1999).

RESULTS

During embryonic development, the GSHPx activity of the 10,000 *g* supernatant fraction of liver homogenates of the tested breeds differed significantly from the overall means. The highest activity was found in breed HW and the lowest, in WPR. Sex also had a significant effect on liver GSHPx activity, with females having significantly higher values than males (Table 1). Moreover, GSHPx activity significantly decreased during embryonic development up to one day of

Table 1. Glutathione peroxidase activity in liver of embryos chicken of different genotypes, sex and age

Items	Glutathione peroxidase activity, U/g protein					Overall mean	Pooled SEM
	days of incubation						
	14th	16th	18th	20th	21st		
Breed effect[1]							
WPR (♂)	2.16	1.44	1.56	1.40	1.24	1.62	0.09
WPR (♀)	2.18	1.39	1.60	1.40	1.60	1.59	0.08
WPR (♂+♀)	2.17^{b}	1.42^{b}	1.58^{a}	1.40	1.42^{a}	1.60^{b}	0.04
NNP (♂)	2.19*	1.64	1.36	1.14	1.23	1.48	0.10
NNP (♀)	2.73	1.74	1.58	1.41	1.27	1.75	0.08
NNP (♂+♀)	2.46^{ab}	1.69^{ab}	1.47^{a}	1.28	1.25^{ab}	1.64^{ab}	0.04
NNNH (♂)	2.34*	1.49*	1.38*	1.35	1.04	1.55	0.08
NNNH (♀)	2.86	2.04	0.85	1.59	1.26	1.74	0.09
NNNH (♂+♀)	2.60^{a}	1.77^{ab}	1.11^{b}	1.47	1.15^{b}	1.63^{ab}	0.04
HW (♂)	2.21*	1.99	1.50	1.18	1.62	1.70	0.09
HW (♀)	2.67	2.16	1.24	1.35	1.63	1.80	0.08
HW (♂+♀)	2.44^{ab}	2.07^{a}	1.37^{ab}	1.26	1.63^{a}	1.75^{a}	0.04
Sex effect							
♂	2.23^{y}	1.64^{y}	1.45	1.27	1.28	1.58^{y}	0.03
♀	2.60^{x}	1.83^{x}	1.32	1.44	1.44	1.73^{x}	0.03
Age effect	2.42^{c}	1.74^{d}	1.38^{e}	1.35^{e}	1.36^{e}		

[a,b] means for genotypes *(♂+♀)* with different letters within each column are significantly different (breed effect) (P<0.05)

[c,d,e] means for age with different letters within row are significant different (age effect) (P<0.05)

[x,y] means for sex with different letters within each column are significantly different (sex effect) (P<0.05)

[*] significant differences within the breed between males and females (P<0.05)

[1] WPR - White Plymouth Rock; NNP - Naked Neck Plymouth; NNNH - Naked Neck New Hampshire; HW - Hungarian White

age. Breed and sex interaction showed higher GSHPx activity in females than in males in all genotypes except WPR. Breed and day of incubation interaction of GSHPx activity of liver embryo differed significantly among breeds in all age groups, but these differences were not consistent and were the highest on the 16th day of incubation. Significant differences were obtained in age and sex interaction, where females had higher activity than males, except on the 18th day of incubation. Breed, age and sex interaction differed significantly as shown in Table 1.

During post-hatching development, the overall mean of GSHPx activity in

RBC of breed HW was the highest and of WPR, the lowest. Sex significantly influenced enzyme activity, with males showing higher activity than females (Table 2). Age also significantly influenced GSHPx activity in RBC. It was the

Table 2. Gluathione peroxidase activity in red blood cell haemolysates of chickens of different genotypes, sex and age

Items	Glutathione peroxidase activity, U/g protein						Overall mean	Pooled SEM
	1st day	4 weeks	8 weeks	12 weeks	SM	HEP		
Breed effect[1]								
WPR (♂)	4.52	11.02*	8.03	6.21	6.84	4.55	6.86	0.20
WPR (♀)	4.30	6.66	8.99	5.73	5.70	3.68	5.84	0.20
WPR (♂+♀)	4.40^{b}	8.84^{b}	8.51^{b}	5.97^{b}	6.27^{b}	4.12^{b}	6.33^{b}	0.14
NNP (♂)	6.49	10.72*	5.68	5.39	7.01	4.25	6.5	0.20
NNP (♀)	5.04	9.34	5.20	4.42	7.15	5.24	6.07	0.20
NNP (♂+♀)	5.77^{a}	10.03^{ab}	5.44^{b}	4.91^{b}	7.08^{ab}	4.74^{b}	6.38^{b}	0.14
NNNH (♂)	3.30	10.49*	7.87	7.77	6.80	7.45*	7.28	0.20
NNNH (♀)	2.43	8.46	6.91	9.40	6.81	4.86	6.48	0.20
NNNH (♂+♀)	2.87^{b}	9.48^{b}	7.39^{b}	8.59^{a}	6.81^{b}	6.15^{ab}	6.88^{b}	0.14
HW (♂)	3.18	10.13	9.33*	7.05	8.55	6.11	7.41*	0.20
HW (♀)	3.80	10.27	11.52	6.53	7.53	6.30	7.66	0.20
HW (♂+♀)	3.49^{b}	10.20^{a}	10.43^{a}	6.79^{b}	8.09^{a}	6.21^{a}	7.53^{a}	0.14
Sex effect								
(♂)	4.37	10.59^{x}	7.73	6.60	7.32	5.59	7.03^{x}	0.10
(♀)	3.89	8.68^{y}	8.16	6.52	6.80	5.02	6.51^{y}	0.10
Age effect	4.13^{e}	9.64^{c}	7.94^{d}	6.66^{d}	7.06^{d}	5.31^{e}		

^{a,b} means for genotypes *(♂+♀)* with different letters within each column are significantly different (breed effect) (P<0.05)

^{c,d,e} means for age with different letters within row are significant different (age effect) (P<0.05)

^{x,y} means for sex with different letters within each column are significantly different (sex effect) (P<0.05)

* significant differences within the breed between males and females (P<0.05)

SM - age at sexual maturation; HEP - age at highest egg production

[1] the explanation - see Table 1

lowest in day-old chicks, increased up to 4 weeks of age and then decreased until the period of higher egg production. Breed and sex interaction showed higher enzyme activity in males than females in all genotypes except breed HW. There were significant differences in GSHPx activity of RBC among breeds in all age groups, but they were not consistent in different age groups. At 8 weeks of age highly significant differences were found among breeds. Age and sex

interaction was also significant; males had higher enzyme activity than females in all age groups except at 8 weeks. Breed, age and sex interactions showed wide variations between males and females in different age groups among the tested breeds. Phenotypic variations in GSHPx activity of BP in different breeds during post-hatching development are summarized in Table 3. Concerning breed effect, WPR had the highest and NNP the lowest enzyme activity in BP.

Table 3. Gluathione peroxidase activity in blood plasma of chickens of different genotypes, sex and age

Items	Glutathione peroxidase activity, U/g protein						Overall mean	Pooled SEM
	1 day	4 weeks	8 weeks	12 weeks	SM	HEP		
Breed effect[1]								
WPR (♂)	11.79*	9.42*	6.13	5.83*	7.08	7.02*	7.88	0.15
WPR (♀)	9.54	13.44	7.04	7.78	6.96	5.53	8.38	0.15
WPR (♂+♀)	10.67^{ab}	11.43^{a}	6.59^{b}	6.80^{a}	7.02^{a}	6.27^{ab}	8.13^{a}	0.11
NNP (♂)	9.38	8.70*	6.50	4.90	6.20	6.31	7.00	0.15
NNP (♀)	9.05	6.77	6.90	5.52	4.87	6.74	6.64	0.15
NNP (♂+♀)	9.22^{b}	7.74^{b}	6.70^{b}	5.21^{b}	5.64^{b}	6.53^{ab}	6.82^{b}	0.11
NNNH (♂)	12.41*	6.93	7.43	5.74*	4.86	6.31	7.30	0.15
NNNH (♀)	10.98	7.75	7.06	7.30	4.27	6.85	7.37	0.15
NNNH (♂+♀)	11.74^{a}	7.39^{b}	7.24^{b}	6.52^{ab}	4.56^{b}	6.58^{a}	7.33^{ab}	0.11
HW (♂)	8.03	11.45*	7.41*	5.69*	5.53	6.04	7.36	0.15
HW (♀)	7.79	8.72	9.80	3.82	5.58	5.19	6.80	0.15
HW (♂+♀)	7.91^{b}	10.04^{b}	8.60^{a}	4.75^{b}	5.55^{b}	5.62^{b}	7.08^{ab}	0.11
Sex effect								
(♂)	10.40^{x}	9.16	6.87^{y}	5.54	5.92	6.42	7.38	0.10
(♀)	9.34^{y}	9.15	7.70^{x}	6.10	5.42	6.08	7.30	0.10
Age effect	9.87^{a}	9.15^{a}	7.28^{b}	5.82^{c}	5.77^{c}	6.25^{c}		

^{a,b} means for genotypes *(♂+♀)* with different letters within each column are significantly different (breed effect) (P<0.05)

^{c,d,e} means for age with different letters within row are significant different (age effect) (P<0.05)

^{x,y} means for sex with different letters within each column are significantly different (sex effect) (P<0.05)

* significant differences within the breed between males and females (P<0.05)

SM - age at sexual maturation; HEP - age at highest egg production

[1] the explanation - see Table 1

Sex affected GSHPx activity of BP; males showed higher activity than females. Regarding age effect, enzyme activity in BP decreased from hatching until the age of sexual maturation and there was a moderate increase at the age of peak egg pro-

duction. Breed and sex interaction was significant, males in NNP and HW breeds had higher GSHPx activity in BP, and females showed higher activity in WPR and NNNH breeds (Table 3). Also, there are significant differences in enzyme activity of BP among breeds in all age groups. Variation in GSHPx activity of BP showed a fluctuating pattern between breeds as they aged. In respect of sex and age significantly higher activity was found in males as compared to females on the first day, at sexual maturity, and at peak of egg production, while females showed higher activity than males at 8 and 12 weeks of age. Breed, age and sex interaction was statistically significant. However, differences between males and females in each age group showed wide variation among breeds.

Significant differences in egg weight (Table 4) were found among the breeds during the incubation period. Breed NNP had the highest egg weight on the 14th, 18th and 20th days of incubation, while NNNH had the highest egg weight on the 16th day of incubation. HW had the lowest egg weight during the whole period of incubation.

Table 4. Egg weight of chickens of different genotypes, sex and age, g

Item	Days of incubation				Overall mean	Pooled SEM
	14th	16th	18th	20th		
Breed effect[1]						
WPR (♂)	52.57	49.58	49.73	50.89	50.70	0.74
WPR (♀)	53.55	54.99	52.45	50.09	52.77	0.66
WPR (♂+♀)	53.06^{ab}	52.29^{ab}	51.09^{ab}	50.50^{ab}	51.73^{b}	0.50
NNP (♂)	59.14	52.70	57.25	55.18	56.07	0.74
NNP (♀)	56.33	51.84	53.08	55.06	54.00	0.60
NNP (♂+♀)	57.73^{a}	52.27^{ab}	55.17^{a}	55.12^{a}	55.07^{ab}	0.48
NNNH (♂)	56.42	54.92	54.17	54.02	54.88	0.65
NNNH (♀)	58.30	54.94	55.30	52.70	55.31	0.72
NNNH (♂+♀)	57.36^{ab}	54.93^{a}	54.74^{ab}	53.36^{ab}	55.10^{a}	0.49
HW (♂)	48.77*	45.48	46.67	44.56	46.37	0.74
HW (♀)	42.48	45.28	45.94	41.66	43.84	0.65
HW (♂+♀)	45.62^{b}	45.38^{b}	46.31^{b}	43.11^{b}	45.11^{b}	0.49
Sex effect						
♂	54.23	50.67	51.96	51.16	52.00	0.36
♀	52.66	51.76	51.70	49.88	51.50	0.33

^{a,b} means for genotypes *(♂+♀)* with different letters within each column are significantly different (breed effect) (P<0.05)

* ignificant differences within the breed between males and females (P<0.05)

^{1} the explanation - see Table 1

Significant differences in average body weight were found among breeds in all age groups, (Table 5) WPR had the highest BW at 4 and 12 weeks of age, SM and at the age of peak egg production; NNP had the highest at 8 weeks of age.

HW had the lowest BW in all age groups. Males had significantly higher BW than females at the age of SM and peak egg production.

Table 5. Body weight of chickens of genotypes, sex and age, kg

Items	1 day	4 weeks	8 weeks	12 weeks	SM	HEP	Overall mean	Pooled SEM
Breede effect[1]								
WPR (♂)	0.038	0.37	0.80	1.42	3.05*	3.38*	1.51	0.024
WPR (♀)	0.039	0.34	0.81	1.44	2.43	2.33	1.23	0.024
WPR (♂+♀)	0.039^{ab}	0.36^{a}	0.80^{ab}	1.43^{a}	2.74^{a}	2.85^{a}	1.37^{a}	0.017
NNP (♂)	0.038	0.34	0.90	1.43*	2.95*	3.30*	1.49	0.024
NNP (♀)	0.044	0.37	0.80	1.18	2.14	2.30	1.13	0.024
NNP (♂+♀)	0.042^{a}	0.35^{ab}	0.85^{a}	1.31^{ab}	2.54^{ab}	2.80^{a}	1.31^{b}	0.017
NNNH (♂)	0.043	0.35	0.84	1.17	3.17*	3.31*	1.48	0.024
NNNH (♀)	0.039	0.33	0.73	1.29	2.17	2.09	1.11	0.024
NNNH (♂+♀)	0.041^{ab}	0.34^{ab}	0.79^{ab}	1.23^{ab}	2.67^{ab}	2.71^{a}	1.29^{b}	0.017
HW (♂)	0.033	0.26	0.58	1.04	2.22*	2.27*	1.07	0.024
HW (♀)	0.035	0.22	0.61	0.91	1.76	1.92	0.91	0.024
HW (♂+♀)	0.034^{b}	0.24^{b}	0.59^{b}	0.98^{b}	2.00^{b}	2.10^{b}	0.99^{b}	0.017
Sex effect								
(♂)	0.039	0.32	0.71	1.16	2.78^{x}	2.70^{x}	1.28*	0.012
(♀)	0.041	0.29	0.67	1.13	2.11^{y}	2.14^{y}	1.06	0.012

^{a,b} means for genotypes *(♂+♀)* with different letters within each column are significantly different (breed effect) (P<0.05)

^{x,y} means for sex with different letters within each column are significantly different (sex effect) (P<0.05)

* significant differences within the breed between males and females (P<0.05)

SM - age at sexual maturation; HEP - age at highest egg production

[1] the explanation - see Table 1

A significant negative correlation was found between embryo liver GSHPx activity and egg weight (-0.24; P≤0.01) and between RBC and BP GSHPx activity with BW (-0.32 and -0.44; P≤0.01). Also, a significant negative correlation was found between the GSHPx activity of the liver and RBC (-0.54; P≤0.01), while significant positive correlations were shown between enzyme activity of liver and BP (0.66; P≤0.01) and also between BP and RBC (0.32; P≤0.01).

DISCUSSION

The objectives of the present study were to identify sources of variation in GSHPx activity, with potential use as early predictors for indirect selection that may be associated with performance traits. GSHPx activity of different tissues may be a candidate for use in indirect selection if there is high variation among breeds and is correlated with performance. An attempt was made to assess the relative importance of these factors by comparing GSHPx activity of different chicken breeds to obtain some information about the possible genetic background of the differences of the GSHPx activity in different tissues. The other purpose was to obtain information about its correlation with some production traits, age and sex under standardized conditions. Environment and diet were the same for all parent stocks, and eggs were incubated under uniform conditions. This suggests that the observed differences among breeds are genetic. Thus, the results appear to support the results of Mizuno (1984) and Shen et al. (1992), who reported breed differences in the activity of GSHPx in whole blood of chickens. There is considerable variation in GSHPx activity of different breeds and this presumably reflects differences in the metabolism of a range of different compounds. If further studies confirm genetic regulation of enzyme activity, it could be used as a selection criterion. The present results clearly indicate that the Hungarian White breed has higher enzyme activity in the liver and RBC than other breeds that are not indigenous Hungarian breeds, which supports the opinion that indigenous Hungarian breeds are more resistant to oxidative stress. It is also interesting to note that, given the tissue-specificity and breed-specific developmental profile of embryos and chicken GSHPx activity, it may be argued that genetic regulatory mechanisms may exist that are capable of modulating enzyme activity. Such regulatory elements are expected to play a vital role in offering protection against oxidative tissue damage because GSHPx plays a pivotal role in the enzymatic antioxidant defence against oxygen free radicals (Surai, 2002).

Our results indicate that females had higher liver enzyme activity than males during embryonic development and at the age of one day in all studied breeds except in WPR. Similar results were obtained with GSHPx activity in rat liver, where females had higher activity than males (Debski et al., 1992).

In general, studies of variations in GSHPx activity with ageing have shown a mixed pattern of increases and decreases that are both tissue- and species- dependent. The results of the present study show that enzyme activity decreased with age in the liver during embryonic development up until hatching, which is in disagreement with the previous finding of Gaál et al. (1995). The results of the present study also indicate that RBC GSHPx activity decreased from day one of

age until 12 weeks of age, subsequently increasing until sexual maturity and then decreasing again to the age of peak egg production. BP enzyme activity decreased with age from one day until peak egg production. In agreement with our observations, Godin et al. (1995) reported that RBC and BP GSHPx activity decreased with age in Japanese quail.

Negative correlations were found between GSHPx activity of liver and egg weight, and also between BP and RBC. The negative correlations between production traits and GSHPx activity in BP, RBC and liver that were obtained in the present experiment are similar to the results reported by LaVronga and Combs (1982). Significant negative correlations between production traits and GSHPx activity in BP, RBC and liver may represent an adaptation mechanism to relatively low selenium intake, particularly in animals with high growth rates, but further research is needed to prove that hypothesis.

The significant correlations among liver, RBC and BP GSHPx activity indicate that measurement of enzyme activity in one tissue can be used as a useful indicator for enzyme activity in other tissues. However, further research is needed to prove this hypothesis.

CONCLUSIONS

In conclusion, the existence of genetic variation in GSHPx activities in different chicken breeds during all stages of development suggests that GSHPx activity is genetically regulated. This finding indicates that GSHPx activity of different tissues may be a candidate for use in selection to improve performance and resistance against oxidative stress.

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