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Hepatic Metabolism of some Breeds of Chickens

Shoukry, H. M. S. ; A. A. El-Shafei ; M. A. Al-Gamal and A. A. A. Abdel-Kawy
Department of Animal Production, Faculty of Agriculture, Al-Azhar University, Nassr City, Cairo, Egypt.
Corresponding author: abdelkawyelghoul@azhar.edu.eg

ABSTRACT

An experiment was conducted to study the differences in liver metabolism of some chicken breeds had different levels of domestication and production types. Hepatic oxygen consumption (HOC), liver weight percentage, liver glycogen, liver fat and Plasma lipids profiles of 180 birds of Dandarawi (D), Lohmann selected leghorn (L.S.L) and Cobb^{500} chicks were assayed. The experiment was terminated at 8 weeks of age. Breed had significant effect on hepatic oxygen consumption, liver weight percentage, liver glycogen, total cholesterol and high-density lipoprotein (HDL). The Dandarawi had significantly ($P \leq 0.05$) higher HOC and liver glycogen compared to L.S.L and Cobb^{500} chicks. Meanwhile, the Cobb^{500} chicks had significantly ($P \leq 0.05$) lower liver weight percentage and had significantly ($P \leq 0.05$) higher total cholesterol and HDL compared to D and L.S.L chicks. The effect of sex was also noticed in liver weight percentage, the female had significantly ($P \leq 0.05$) higher liver weight when compared to male chicks. The effect of interactions between breed and sex was also noticed in liver fat, the male Cobb^{500} had significantly ($P \leq 0.05$) higher liver fat when compared to female Cobb^{500}, male and female D and L.S.L. chicks. It can be concluded that domestication and intensive selection for growth rate and egg production has resulted in alterations in hepatic metabolism, liver glycogen, and, fat and plasma lipids profiles.

Keywords: Broilers, Dandarawi, Leghorn, Hepatic oxygen consumption, Liver fat, Liver glycogen)

INTRODUCTION

Domestication is a directive adaptation and the course of domestication can be influenced by man through artificial selection (Price and King ,1968). Domestication resulted also in basic changes in the behavior, physiology and production of the bird (Al-Nasser *et al.,* 2007). Faure *et al*., (2003) divided selection for domestication into three phases. First phase involved choosing appropriate species for domestication. The second phase soon followed and it lasted until the1950s. In this phase, changes had been made led to propagation of favorable characters. These changes had resulted from both 'natural' and unconscious artificial selection. Unconscious artificial selection contributed to the domestication phenomenon as farmers eliminated animals that had undesirable characters. Commercial breeding companies launched the third phase, which involved conscious artificial selection for adaptability, and physiological and behavioral changes to produce commercial synthetic strains.

During the course of domestication from Jungle fowl (Undomesticated) up to the recent commercial synthetic strains (Fully domesticated) undesirable characters are eliminated, other characters are improved, and some others become less effective. A third class of domestication is Semi- domesticated chickens which may be represented by village fowl such as Dandarawi chicken. This Egyptian native chicken have undesirable characters that were not completely improved or eliminated such as low egg production, light body weight and skeletal deformations represented as a fifth toe in about 40 % of a flock (Shoukry).

Mitochondria are the site of electron transport and oxidative respiratory chain in the cell thence the organelle of oxygen consumption (Boveris and Chance, 1973; Chance *et al*., 1979). Mitochondrial oxidative phosphorylation accounts for approximately 90% of cellular oxygen uptake and provides more than 80% of the energy requirement for cellular life metabolism (Papa, 1996). Dziewiecki and Kolataj (1976) stated that the genetics has profound effect over mitochondrial function for example differences in cellular oxygen utilization rates between chicken breeds. HOC may directly reflect the status of cellular metabolism activity in the body. Differences in broiler growth and feed efficiency (FE) have been illuminated in part by differences in mitochondrial function and biochemistry of liver in broilers. Thus, inefficiencies related with mitochondrial dysfunction could be hypothesized to have great influence on the growth performance and phenotypic expression of FE in animals (Bottje *et al*., 2002, and Iqbal *et al*., 2004). Al-Gamal (2009) found significant differences ($P \leq 0.05$) among D, Fayoumi, and L.S.L laying hens in hepatic oxygen consumption (HOC). In his study D hens showed significant ($P \leq 0.05$) higher HOC than that of the two other breeds.

Disorders of lipids metabolism in birds are, to a large extent, determined by the type of stressors the birds are exposed to (Meluzzi *et al*., 1992). Liver storage of fat and glycogen as well as plasma lipids profile may reflect energy homeostasis and lipids mobilization in the body. Ruff *et al*., (1981) stated that fat content in liver of broilers at 4 weeks of age was found to be 17.3 % based of liver dry weight. However, Patel *et al*. (1981) reviewed that content of liver fat of White Leghorn chicks at 8 weeks of age was 13.2 % based of liver dry weight. Cui *et al*., (2012) stated that the liver fat of Beijing-You chicken was significantly lower than that of Arbor Acres chicken. Normal serum total cholesterol of domestic fowl ranged between 87 and 192 mg/100 ml and triglycerides ranged between 45.7 and 172 mg/100 ml (Meluzzi *et al*., 1992). Soleimani and Zulkifli, (2010) reported that the influence of genotype on serum cholesterol concentration of Red jungle fowl, Village Fowl and commercial broiler chickens was not significant. On the other hand, Bowes *et al*., (1989) stated that the impact of genotype on serum cholesterol of male broiler, female broiler chicks and White Leghorns male at 30 days of age was significant. In their study male broiler chicks showed significantly higher plasma cholesterol than that of each of female broiler and male White Leghorn.

Glycogen as an animal starch plays an important role to store excess carbohydrate in liver birds and mammals to be readily available for the maintenance of glucose homeostasis (Gold, 1970). O'Dea *et al*., (2004) reviewed that no differences in hepatic glycogen content among some chicken breeds. Liver glycogen in growing Leghorn chicks was 2.46 mg /100 mg of liver dry weight (Sarkar, 1971 and 1973). In another study liver glycogen content in broiler chicks at a comparable age was found to be 2.92 mg/100 mg of liver dry weight (Ruff *et al.,* 1981).

The current study was conducted to study the differences in hepatic respiratory metabolism of growing chicks in three breeds of chickens reflect different levels of domestication and types of production.

MATERIALS AND METHODS

Experimental Birds and Management of the Flock:

Experiment was carried out in the Poultry Research Station, Animal Production Department, Faculty of Agriculture, Al-Azhar University, Nasr City, Cairo, Egypt. A total number of 180 day-old chicks, 60 birds of each of Dandarawi, L.S.L and Cobb500 had been used. The experiment was lasted for 8 weeks between 21st of July and 21st of September, 2014. Day-old chicks were reared in floor pens with density of (6 birds/m2) until the end of the experiment. Light regime for D and L.S.L. followed natural light period of the year (L:13 and D:11 hrs) and for Cobb500 followed Continuous light during experimental period. They had free access to food and water. Birds were healthy and clinically monitored and they had been vaccinated on a standard vaccination schedule. The birds were fed commercial rations for layer and broiler chicks according to their types from Feedmix Egypt Feed Industry Company at El-Obour City, Cairo. Dandarawi and L.S.L chicks were fed the same commercial ration. The specifications of the starter and grower rations used in the experiment are presented in Table (1).

Table 1. Analysis of experimental rations on dry basis:

	Layer Starter ration (D and L.S.L.)	Broiler Starter ration ($Cobb^{500}$)	Layer Grower ration (D and L.S.L.)	Broiler Grower ration ($Cobb^{500}$)
Crude protein (%)	20	23	18	21
Metabolizable energy (kcal/kg)	2900	3000	2890	3100
Crude fiber (%)	3.82	3.8	3.61	3.5
Crude fat (%)	3.87	5.6	3.18	5.8

Experimental Design and Procedures:

At the beginning of the experiment, day-old chicks were divided into three experimental groups, 60 birds each of mixed sex. Averages of body weight in the 3 experimental groups were apparently uniform. At 8 weeks of age 10 birds from each breed were randomly chosen and weighed individually to the nearest 0.1g. Birds were then slaughtered and sexed upon autopsy by gonads shape. Liver was excised and weighed to the nearest 0.1 g. Apex of liver right lobe was sampled to measure HOC, rest of the liver was used for chemical analysis.

HOC was measured using constant volume manometric technique by Warburg apparatus. The sampled tissues were saved in Hanks media as described by (Wasley, 1972). All tissue samples were in contact with ice until analyses. A total volume of 2.5 ml from the tissue sample with the Hank's media was placed in the flask of Warburg apparatus and strap of filter paper soaked with 30% KOH was put in the well of the flask to absorb CO2 then the reading of the manometer was recorded after incubation for two hours with agitation at 30ºC to determine the O2 consumed by the tested tissues as described by Umbreit, *et al*., (1972). Oxygen consumption was calculated on the dry tissue basis as µl .h-1/100mg dry weight.

For liver glycogen and fat, liver samples were kept in aluminum foil and frozen at -20◦C till analysis. Liver samples were dried in oven at 60 ºC for 48 hrs. Assay of glycogen in liver was done spectrophotometrically according to the methods described by Seifter *et al*. (1950). The method was based on hydrolyzing the glycogen into glucose by hot 30% KOH. Fat content in the liver samples were determined gravimetrically, after extraction with diethyl ether in a Soxhlet apparatus for 8 h, according to the Association of Official Analytical Chemists methods (1984).

Blood Sampling:

Blood was sampled from 20 birds from each breed were randomly chosen before slaughtering at the end of the experiment. Blood was drawn from the jugular vein in tubes filled with 1mg Na-EDTA /1ml blood. Sampling time was between 10-12 a.m. Blood was centrifuged at 3000 rpm. for 15 minutes to separate the plasma. Plasma was then collected and kept frozen at -20◦C till analysis. The concentration of total cholesterol, triglycerides, and HDL were determined spectrophotometrically by commercial Kits (Diamond Company, Cairo, Egypt).

Ambient Temperature and Humidity:

Birds were reared in average ambient temperature 30 °C with average minimum and maximum temperature 28 and 32°C, respectively. The average relative humidity was 54% with average minimum and maximum relative humidity 37 and 69%, respectively.

Statistical Analysis:

Two-way analysis of variance was done to test the effects of breed, sex, and their interaction on HOC and liver fat and glycogen contents, meanwhile, one-way analysis of variance was done to test the differences among breeds in plasma lipids profile. Least squares means was used for means separation. All statistical analyses were done according to Winer, (1971). Procedure GLM of SAS software (SAS, 1988) was used to perform the statistical analyses.

RESULTS AND DISCUSSION

Hepatic oxygen consumption and chemical composition of liver:

The interactions between breed and sex in HOC,and liver glycogen were not significant (Table, 2). Meanwhile, significant main effect of breed was found in each of HOC, and liver glycogen. No significant main effect of sex was found in the studied variables in table 2. On the other hand, the interaction between breed and sex was significant ($P \leq 0.05$) in liver fat (table, 2).

The average values of HOC in Dandarawi, L.S.L., and Cobb500 chicks were 5.271, 2.761, and 3.004 µl .h-1/100mg dry weight, respectively. No significant differences were observed between L.S.L. and Cobb500 chicks. However, HOC of Dandarawi chicks was significantly (P≤0.05) higher than that of the two other breeds. Similar trend was found by Toyomizu *et al*., (2011). They reported that both of the rates of the phosphorylation system module and the proton leak module were slightly lower in liver mitochondria of meat-type chickens than in the laying-type. This resulted in better efficiency of respiratory metabolism in layer-type compared to meat-type chicks. Al-Gamal (2009) found that the HOC at 29 weeks of age of Dandarawi, and L.S.L. laying hens were found to be 2.70, and 1.14 µl. h-1/100 mg dry weight, respectively, the difference was significant (P≤ 0.05). Genetic differences were also shown in some aspects of cellular respiration had been reported in chickens such as, efficiency of oxidative phosphorylation (Mukherjee *et al.,* 1970), and mitochondrial function (Iqbal *et al.,* 2005). On the other hand, Brown *et al*., (1986) reported that respiration rate of liver mitochondria did not differ significantly between Hubbard White Mountain cross broiler hens and that of White Leghorn layers. Bottje *et al.* (2006) reported that, mitochondria obtained from low FE broilers appeared to exhibit decreased electron transport chain coupling, and increased electron leak with subsequent increased of radical oxygen species (ROS) production.

The averages of liver glycogen for Dandarawi, L.S.L., and $Cobb^{500}$ chicks were 95.240, 17.950, and 16.185 mg/g dry weight, respectively (Table, 2). No significant differences were noticed in liver glycogen between L.S.L. and $Cobb^{500}$ chicks. However, Dandarawi chicks showed significant (P≤0.05) higher liver glycogen than that of the two other breeds. O'Dea *et al*., (2004) reported that the different chicken synthetic strains, which had been subjected to intensive selection programs showed striking differences in growth and metabolism. There is no difference in hepatic glycogen content between L.S.L. and $Cobb^{500}$ in the present study. Trampel *et al.* (2005) stated that the value of liver glycogen in broiler chicks at 49 days of age was 39.4 mg/g dray weight. Meanwhile, Hazelwood and Lorenz (1959) found that the values of liver glycogen in male broiler chickens aged 8 weeks were 18.50 mg/g dry weight. In Growing Leghorn, Sarkar (1971 and 1973) found that the values of liver glycogen in chicks aged 4 to 6 weeks were 2 .46 mg per 100 mg of liver.

Significant (P≤ 0.05) interaction between breed and sex in liver fat was noticed (Table, 2). In Cobb500 male liver fat was significantly (P≤0.05) higher than that of female. However, the liver fat content of the two other breeds did no differ significantly between sexes (Table, 2). The Cobb500 male showed significant (P≤0.05) higher liver fat than that of Dandarawi and L.S.L. cockerels. However, there were no significant differences among the pullets of the three breeds in liver fat content. The averages of liver fat of Dandarawi, L.S.L. and Cobb500 pullets were 8.203, 8.008, and 10.189 (%), respectively. Meanwhile, the averages of liver fat of Dandarawi, L.S.L. and Cobb500 cockerels were 8.240, 7.177, and 13.241 (%), respectively (Table, 2). Patel *et al.* (1981) reviewed that the values of liver fat for White Leghorn chicks at 8 weeks of age was 13.2% dry mater. Breed difference in liver fat content was found by Cui *et al.*, (2012). They found that the liver fat of Beijing-You chicken (a local breed) was significantly lower than that of Arbor Acres chicken. That might be because the growth rate of Arbor Acres chicken was higher than that of Beijing-You chicken and subsequently, the energy consumption and fat deposition during development would be different between the two breeds Cui *et al.*, (2012). Similar trend was found in the present study, where fat content in male Cobb500 liver was significantly (P ≤ 0.05) higher than that of L.S.L. and D males (Table, 2).

Table 2. The effect of sex, breed and their interaction on hepatic oxygen consumption, percentage of liver weight, liver glycogen, and liver fat in Dandarawi, L.S.L., and $Cobb^{500}$ breeds of chickens at 8 weeks of age.

Variables		Oxygen consumption ($\mu l .h^{-1}$/100mg dry weight)	Liver weight (g/100g body weight)	Liver glycogen (mg/g dry weight)	Liver fat (g/100g dry weight)
Breeds					
D		5.271^{1a}±0.12	2.704^{a}±0.14	95.240^{a}±5.93	8.222±0.54
L.S.L		2.761^{b}±0.12	2.715^{a}±0.14	17.950^{b}±5.93	7.593±0.54
$Cobb^{500}$		3.004^{b}±0.12	1.753^{b}±0.14	16.185^{b}±5.93	11.593±0.54
Sex					
F		3.803±0.09	2.592^{a}±0.12	45.864±4.84	8.800±0.44
M		3.555±0.09	2.189^{b}±0.12	40.386±4.84	9.553±0.44
Breed*Sex					
D	F	5.474±0.16	2.921±0.20	108.944±8.38	8.203±0.77
	M	5.068±0.16	2.488±0.20	81.535±8.38	8.240^{B}±0.77
L.S.L	F	2.818±0.16	3.030±0.20	13.589±8.38	8.008±0.77
	M	2.704±0.16	2.399±0.20	22.311±8.38	7.177^{B}±0.77
$Cobb^{500}$	F	3.116±0.16	1.825±0.20	15.058±8.38	10.189^{b}±0.77
	M	2.892±0.16	1.681±0.20	17.312±8.38	13.241^{aA}±0.77
Source of variance					
Breed		0.000	0.000	0.000	0.000
Sex		0.075	0.023	0.431	0.242
Breed*Sex		0.669	0.493	0.092	0.046

1Least square means ± Standard error.

A,B Means having different letter exponents are significantly different (P≤ 0.05) among breeds within sex.

a,b,c Means having different letter exponents are significantly different (P≤ 0.05) among rows of main effects (Breed or sex) or between sexes within breed whenever the interaction is significant.

Liver weight percentage:

The interaction between breed and sex in liver weight percentage was not significant (Table, 2). Meanwhile, significant main effects of breed and sex were found in the same variable. Liver weight percentage of $Cobb^{500}$ was significantly (P ≤ 0.05) higher than that of D and L.S.L. The values of this variable were 1.753, 2.715, and 2.704 g/100g body weight for $Cobb^{500}$, L.S.L., and D, respectively. Liver weight percentage of females was significantly (P ≤ 0.05) higher than that of male. The values were 2.592 and 2.189 g/100g body weight, respectively.

Plasma Lipids profile:

The main effect of breed on total cholesterol and HDL were significant (P≤0.05), but no significant effect of breed on triglycerides (Table, 3). Cobb^{500} chicks had significant (P≤0.05) higher total cholesterol and HDL than those of the two other breeds. However, no significant difference was observed between Dandarawi and L.S.L. chicks in both variables. The averages of total cholesterol in Dandarawi, L.S.L., and Cobb^{500} chicks were 106.504, 105.610, and 127.967 mg/dl, respectively. Meanwhile, the averages of HDL in Dandarawi, L.S.L., and Cobb^{500} chickens were 66.348, 77.691, and 97.926 mg/dl, respectively (Table, 3). No significant differences were found among breeds in triglycerides (Table, 3). The averages of triglycerides of Dandarawi, L.S.L., and Cobb^{500} chicks were 178.698, 171.354, and 162.350 mg/dl, respectively.

These results are partially in agreement with the results obtained by Soleimani and Zulkifli (2010) who found that no significant effect of genotype on serum levels of total cholesterol of Red Jangle Fowl, Village Fowl and broiler chicks. Same results were noticed by Zulkifli *et al.,* (1999) who found that no significant effect of genotype on serum levels of total cholesterol of Red Jangle Fowl and commercial broilers. Bowes *et al*., (1989) reported that the serum total cholesterol was significantly (P ≤ 0.01) higher in male broiler than that in male White Leghorns chicken at 30 days of age. It seems that the rate of hepatic synthesis and secretion of lipids in broiler chicks are higher than those of layer breeds. In addition, the great proportion of synthesized lipids is taken up into abdominal fat pad in broiler chicks higher than that in layers (Griffin and Goddard, 1994).

Table 3. The effect of breed on plasma Total cholesterol, Triglycerides and HDL in Dandarawi, L.S.L., and Cobb breeds of chickens at 8 weeks of age.

Breeds	Plasma lipids profile		
	Total Cholesterol (mg/dl)	HDL (mg/dl)	Triglycerides (mg/dl)
D	106.504^{1b}±6.58	66.348^{b}±6.45	173.698±57.20
L.S.L	105.610^{b}±6.24	77.691^{b}±4.56	171.354±57.20
Coob^{500}	127.967^{a}±6.24	97.926^{a}±4.56	162.330±54.267

1least square means ± Standard error.
a,b Means having different letter exponents are significantly different (P ≤ 0.05) among breeds.

CONCLUSION

The semi-domesticated Dandarawi chicken showed about two folds of HOC and five folds of hepatic glycogen increase compared to the two other fully-domesticated breeds. This indicated that Dandarawi chick was inefficient to direct metabolic energy to growth but rather converted it into glycogen in liver. Dandarawi chicken as a village chicken had not been subjected to a conscious selection. The level of domestication in this regard had its impact on HOC. At the same time the type of production regardless of level of domestication had its impact on lipids metabolism. The males of meat-type chick Cobb^{500} showed higher liver fat content than that of males of the two other non meat-type chicks. The plasma levels of total cholesterol and HDL in meat-type chicks exceeded those of the other two chicks too. Which may be related to higher lipids mobilization in Cobb^{500}. It seems that the higher hepatic synthesis and mobilization of lipids in male meat-type chicks was due to higher lipids uptake by abdominal fat pad (Griffin and Goddard, 1994).

It is advisable screening out more differences in variables of internal environment such as metabolic activities of chick breeds representing different levels of domestication and production types. This may led to use some of these variables in conscious selection hoping to improve the production of Egyptian village chickens.

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أيض الكبد لبعض أنواع الدجاج

هشام محمد صالح شكرى، عبدالرفيع أحمد الشافعى ، محمد عبدالمنعم الجمل و عبدالقوى عبدالغفار عبدالواحد عبدالقوى
قسم الإنتاج الحيوانى- كلية الزراعة- حامعة الأزهر- مدينة نصر- القاهرة

أجريت تجربة لدراسة الاختلافات في أيض الكبد لبعض أنواع الدجاج التى لديها مستويات مختلفة من الإستئناس ونوع الإنتاج. تم تقدير استهلاك الأكسجين في خلايا الكبد -النسبة المئوية لوزن الكبد - جليكوجين ودهن الكبد - ومستوى الليبيدات فى البلازما لعدد 180 طائر من كل من الدندراوى واللوهمان المنتخب من اللجهورن و كتاكيت الكوب500. التجربة تم انهاءها عند عمر 8 أسبوع. كان للنوع تأثير معنوى على استهلاك الأكسجين في خلايا الكبد - النسبة المئوية لوزن الكبد- جليكوجين الكبد- الكوليستيرول والبروتين الدهني عالى الكثافة ، كتاكيت الدندراوى كانت أعلى معنويا بالنسبة لإستهلاك الأكسجين في خلايا الكبد وجليكوجين الكبد بالمقارنة بكتاكيت اللوهمان المنتخب من اللجهورن و الكوب500 بينما كتاكيت الكوب500 كانت أقل معنويًا في النسبة المئوية لوزن الكبد وأعلى معنويا بالنسبة للكوليسترول والبروتين الدهني عالى الكثافة بالمقارنة بكتاكيت الدندراوى واللوهمان المنتخب من اللجهورن. لوحظ تأثير للجنس عل النسبة المئوية لوزن الكبد فوجد أن الإناث كانت أعلى معنويا مقارنة بالذكور. لوحظ أيضا تأثير للتداخل بين النوع والجنس على دهون الكبد حيث وجد أن ذكور الكوب500 كانت أعلى معنويا مقارنة بإناث الكوب وذكور وإناث الدندراوى واللوهمان المنتخب من اللجهورن. ويمكن استنتاج أن الإستئناس والإنتخاب المكثف للنمو وإنتاج البيض أدى إلى تغيرات في أيض الكبد وجليكوجين ودهون الكبد ومستوى الليبيدات فى بلازما الدم. ومن المستحسن فحص المزيد من الاختلافات بالنسبة للمتغيرات فى البيئة الداخلية مثل النشاط الأيضي لأنواع الكتاكيت والتى تمثل مستويات مختلفة من الإستئناس ونوع الإنتاج. وقد يؤدي ذلك إلى استخدام بعض هذه المتغيرات في الإنتخاب الواعى على أمل تحسين إنتاج الدجاج المحلى المصرى.