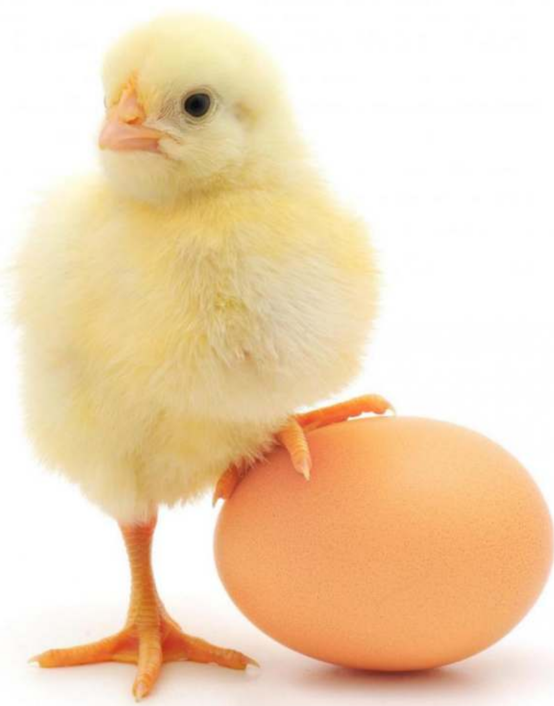
ISSN 1682-8356
ansinet.org/ijps



INTERNATIONAL JOURNAL OF POULTRY SCIENCE

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International Journal of Poultry Science 3 (6): 422-426, 2004

Comparison of Feed Intake, Blood Metabolic Parameters, Body and Organ Weights of Growing Broilers Originating from Dwarf and Standard Broiler Breeder Lines

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Abstract: Growing broilers from three female breeder lines were compared to determine the relationship between feed intake, body weights, relative growth (RG), blood triiodothyronine (T_3) and carbon dioxide partial pressure (pCO_2) levels, heart and liver ratio to body weights in order to establish the dynamics of growth at different periods during rearing. The lines included a standard heavy S line, an experimental (E) line and a Label-type line (L). The E and L lines breeders carry the sex-linked dwarfing "dw" gene and are being used to assess the potential for the "dw" gene to reduce feed intake or lower feed restriction to improve reproductive performance in heavy female broiler parent stock. Four incubation settings, each of 2 replications of 150 eggs /line (total of 3,600 eggs) were incubated. At the end of each incubation setting, samples of chicks were reared in order to record broiler body, heart and liver weights, and to measure thyroid hormone levels and gas pressure in blood during specific periods of growth namely at d 14, 28 or 41 of age. The results showed that although broiler body weights at 14, 28 and 41 d were different between lines (S > E > L) at these times, only the RG during the periods 1-14 d and 15-28 d were different between lines. The RG decreased sharply with increasing age of broilers depending on the lines but become similar during the period of 28 to 41 d. On the contrary, feed intake increased with the age of broilers. Feed conversion ratio (FCR) decreased with age but not different between lines. Heart and liver ratios to body weights as well as pCO_2 levels followed the same trend as RG in relation to the age of broilers and the lines. The levels of T_3 also decreased with increasing age of broilers but at each age these levels were similar between lines. These data suggest a logical positive correlation between T_3, pCO_2, FCR, heart and liver ratios to RG at different stages of growth depending on the lines. It is concluded that selection for fast growth improved broilers growth mainly during the first 4 weeks of rearing in the S line; the dwarf lines also showed high growth during the same period with a higher rate in the E line. The results suggest that heavy broiler production may benefit from the use of the dw E line from the viewpoint of lower feed consumption in both the parent stock and the broilers combined with the higher reproductive performance of the parent stock.

Key words: Broiler breeders, relative growth, metabolic parameters, dwarfism gene, feed conversion ratio

Introduction

It is well known that quantitative selection practice by commercial breeding companies as well as feed improvement lead to an increasing growth rate of commercial broilers. On the other hand, because broiler breeders also consume more feed, grow faster and become heavier (Nicholson, 1998; Havenstein *et al.*, 1994), their reproductive potential is adversely affected. To alleviate this problem, feed restriction at specific periods has been adopted by industry. However, the degree of feed restriction can raise welfare problems. The potential for using the "dw" gene to reduce feed intake or restriction and improve reproduction fitness in broiler breeders is currently being investigated in our laboratory. The effects of these procedures on the progeny also need to be determined. Two types of dwarf broiler parent stocks differing in growth potential have been produced by Hubbard Europe, France. These lines (L and E) carry the sex-linked dwarfing ("dw") gene. The Label-type broiler breeder hen (L-line) is medium-sized, slow growing with high reproductive performance under *ad libitum* feeding. However, the progeny broilers reach market weight later than those of standard heavy broiler breeders (S-line). This line was created for "market differentiation" in France. A second dwarf parent stock, currently an experimental line (E-line), is a heavy broiler type breeder female developed to create a different balance between growth, reproduction and livability with primary emphasis on improving reproduction and livability. This line consumes significantly less feed than the standard S-line parent stock under *ad libitum* feeding. Recently, a comparison of the growth and reproductive performance of these dw lines of breeder hens with the standard commercial (S) line was reported (Heck *et al.*, 2004). A study comparing the embryo physiological parameters of the progeny broilers of E, L and S lines and their relationship with their hatching and posthatch growth performance was also reported (Tona *et al.*, 2004). Progeny growth performance of the E line progeny broiler showed a similar high growth rate as the S-line even though the breeder parent stock had lower body weight and consumed less feed.

The heart and liver are involved in metabolism in different ways but are generally considered as supply organs for metabolism. Their proportions to body weight at different ages may indicate the metabolic levels at different periods during growth. The relationships between the organs, feeding levels and other physiological parameters such as T3 which is known to be the calorigenically active form of thyroid hormone may provide more information on the growth dynamics of different lines of broilers.

The aims of this study were to compare growing broiler blood physiological parameters (gas and triiodothyronine levels), the weight of heart and liver, feed consumption and feed conversion efficiency at different ages and relate them to the pattern of growth rate at different ages. This will allow an evaluation of the metabolic basis of growth differences of the broilers from dwarf breeders against those from the regular heavy S line breeders.

Materials and Methods

Experimental design: Hatching eggs produced by three different lines of broiler breeders (L, E and S) were used in this study. Both the L and E genotypes carry the 'dw' gene while the S genotype is a standard heavy broiler breeder line. The breeders were fed on a standard commercial diet containing 2,750 Kcal/kg energy and 16% crude protein. The L breeders were fed *ad libitum* but both the E line and S line breeders were fed on restricted (or controlled) amounts of the feed as recommended by the breeder company. However, the restriction level for the E was lower than for the S line. Daily feed consumption of the S fed *ad libitum* birds was 210 g during lay but the restricted line had 180 g at peak of production. For the E line, the *ad libitum* group consumed 157 g but the restricted group received 151 g of feed at peak of production. The body weights of the S and E breeders during lay were maintained at 3.8 and 2.8 kg respectively while that of the L breeders was 2.2 kg (as recommended by the breeder company). The eggs were stored for durations ranging between 7 and 12 days.

Four incubation settings, each of 2 replications of 150 eggs/line (total of 3,600 eggs) were incubated at specific dry bulb temperature of 37°C, wet bulb temperature of 29°C and turned once per h through an angle of 90°C.

Body and organs weights: At the end of hatch, samples of 60 1-d-old chicks per line and per incubation replication were reared in pens according to the lines in order to record body, heart and liver weights. Body weights were recorded at hatch and at 14, 28 and 41 days of age. Also, samples of 12 broilers per replication per line were sacrificed at 14, 28 and 41 days of age, respectively, in order to collect heart and liver for their weights recording. Then, for each animal, body weights were used to calculate relative growth (RG) between d 1 and 14, d 14 and 28 or d 28 and 41. For each of the previous periods, RG were expressed as : RG = 100 x (Wf –Wi) / Wi; where Wi = beginning weight of the period and Wf = final weight of the period. Also, heart and liver weights were expressed as percentage of body weight. From 15 to 41 d of the rearing period, feed consumption was recorded for each line. For each pen, individual broiler feed intake (IFI) was calculated from total feed consumption and number of broilers as : IFI = Total amount of feed consumed by the pen / number of broilers actually present. For periods of 14 to 28 d and of 29 to 41 d, IFI was used to determine feed conversion ratio (FCR) as : FCR = IFI / weight gains. Feed intake during the first 14 d were not recorded due to the variable amount of spills of feed from feeding troughs onto litter floors.

Triiodothyronine levels: Blood samples were collected from wing vein. For each line per replication, samples were collected from the 12 broilers per line that were used for determining liver and heart weights at the ages of 14, 28 and 41 days. The T_3 concentrations were measured in plasma samples by radioimmunoassay (RIA) as described previously (Huybrechts *et al.*, 1989 and Darras *et al.*, 1992). Intra-assay coefficients of variation was 4.5%. Antisera and T_3 standards were purchased from Byk-Belga (Belgium).

Gas pressures: Within each line per replication, the 12 broilers used for liver and heart weights at 28 or 41d-old were also used to measure the CO_2 partial pressure (pCO_2) in blood. These measurements were done directly in the blood by means of a blood gas analyzer[1] designed for the measurement of gas levels. The blood samples used for this measurement were collected from wing vein. The measurement was done as quickly as possible after blood collection.

Statistical analysis: The data were processed with the statistical software package SAS version 8.2[1]. Generalized linear regression was used to analyze body weights, RG, feed intake, proportion of heart and liver weights in relation to body weights, pO_2, and T_3 concentrations in relation to lines and age of broiler. The model was as follows:

$$Y_{ijk} = \mu + \alpha_i + \tau_j + (\alpha\tau)_{ij} + e_{ijk}$$

Where Y_{ijk} = body weights, RG, feed intake, proportions of heart and liver weights, pCO_2, T_3 concentrations of broiler from line i with age j; μ = overall mean α_i = main effect of line i; τ_j the main effect of age j; ($\alpha\tau$) = interaction between line and age, and e_{ijk} = random error term for the parameters of broiler k.

Results

Body weights and relative weight gains: Broiler weights at hatch, 14, 28 or 41 d-old and their RG are shown in Table 1. Day-old chicks as well as egg weights at setting from L line were heavier ($P < 0.05$) than those from E and S lines which were similar in weights. At 14 and 28 d-old, broilers from S line were the heaviest and those from L line were the lightest compared with the broilers from E line ($P < 0.001$). At 41 d of age, broilers from S and E line were 672.47 g and 500.74 g heavier respectively, than broilers from L line in absolute weight. When expressed in terms of relative growth (RG), all the lines showed the highest growth speed during the first 14 d followed by a significant reduction in growth speed up to 28 d and with a further significant reduction until 41 d. There were significant differences between lines, in RG at corresponding periods of growth. The S line showed the highest RG until 14 d of age and the L line had the lowest ($P < 0.001$). RG up to 28 d were similar between the S and E lines whereas the RG in the L line was lower ($P < 0.001$). Growth speed until 41 d was similar between lines.

Heart and liver: The proportions of heart and liver weights in relation to body weights are shown in Table 2. In all lines, both proportions of heart and liver decreased with age of broilers ($P < 0.001$). At 14 and 28 d of age, the proportion of heart in broilers from L line was lower ($P < 0.05$) than those of broilers from E and S lines which were similar. At 41 d of age however, the proportions of heart were similar between all lines. At 14 d-old, the proportion of liver was lower ($P < 0.05$) in broilers from L line compared to that of broilers from E and S lines which were comparable. At 28 or 41 d-old, the proportion of liver was similar between lines.

Triiodothyronine and pCO_2 levels: Table 2 shows that T_3 levels decreased with the age of broilers ($P < 0.001$). At each age, plasma T_3 levels were similar between lines. The pCO_2 levels also decreased with increasing age of broiler (Fig. 1). At 28 and 41 d-old, blood pCO_2 in broilers from L line were lower ($P < 0.05$) compared with those of broilers from E and S lines which were similar.

Feed consumption: The daily feed intake of the broilers of the 3 lines during the experimental (d 14 to d 41) period are shown in Fig. 2. Between 14 and 28 d of age, daily feed intake was similar between the S and E line broilers, but feed intake by the L was lower than those of S and E ($P< 0.001$). Daily feed intake between 28 and 41 d was significantly different between the 3 lines; the S line being highest and lowest in the L line. Feed conversion ratios (FCR) at 14-28 d were 1.73 for the S and E lines and 1.66 for the L line. Between 28-41 d FCR was similar between lines and was respectively 2.21 for the S, 2.11 for the E and 2.15 for the L lines.

Discussion

It is generally agreed that physiological parameters such as plasma T_3 levels and blood CO_2 pressures or the activities of organs such as the liver and heart are indicators for metabolic levels in animals. The results from this study demonstrate the existence of positive correlation between the levels of blood T_3, pCO_2, the proportions of liver or heart relative to body weight and the RG of the broilers at different ages. So, age effects are clearly seen as well as age-related correlations between these parameters.

The differences in RG between lines were reduced with increasing age of broilers and disappeared at 41 d of age. Mao *et al.* (1998) and Tona *et al.* (2004) reported that d-old chicks with different or similar weights begin, respectively, to converge to similar body weights or to diverge in body weights from the end of week 3 of rearing. Ricklefs (1985) also, reported an increase in exponential growth rate during the first two weeks after hatching. Similar to changes in RG, the changes in T_3 and pCO_2 levels as well as proportions of liver and heart followed the same trend as the broilers become older.

It is surprising that although broiler weights as well as their RG at 14 d of age differed between genetic lines, there were no differences between T_3 levels. A similar observation was reported during embryonic development of these lines by Tona *et al.* (2004). The decrease in T_3 levels with increasing age of broiler observed in this study is consistent with the general trend of T_3 levels in other broiler strains (Mao et al., 1998 ; Buyse *et al.*, 1991 and Malheiros *et al.*, 2002). This decrease may be due to decreasing metabolic levels with increasing age of broilers as evidenced from the decreasing RG. Decreases in RG according to the age of broilers can then be related to differences in T_3 levels (Kühn *et al.*, 1982).

Our data show a positive correlation between RG and pCO_2 suggesting reduction in metabolic rate with age and therefore a reduction in growth speed of the broilers. Similarly, the decrease in pCO_2 level with age matches that of T_3 further strengthening the argument for decreasing metabolic rate. Contrary to Scheele *et al.* (2003), this study shows a negative correlation between age of broiler and blood pCO_2 levels. However, it is worthy to note that Scheele *et al.* (2003) used broilers selected on the basis of other selection criteria (e.g.:susceptibility to ascites) while this study investigated genetic lines differing in growth rate. The age x line interaction effect on pCO_2 observed in this study may be the manifestation of the different body weights between the lines.

It has been shown that selection for production traits

Table 1: Body weights and RG (mean ± SEM) according to lines and age of broilers

Lines	Body weights (g)				Relative growth (%)		
	1 d-old	14 d-old	28 d-old	41 d-old	1-14 d	14-28 d	28-41d
L	43.23^a±0.39	280.08^c±4.23	909.34^c±10.67	1650.33^c±18.47	548.38^c±9.92	233.92^b±3.75	83.58±1.07
E	41.31^b±0.34	330.71^b±6.20	1181.57^b±14.85	2151.07^b±28.22	701.66^b±12.39	270.60^a±6.61	83.34±1.56
S	41.31^b±0.30	347.56^a±5.12	1279.47^a±16.19	2322.80^a±31.83	745.66^a±14.89	271.40^a±5.46	81.77±1.90

$^{a, b, c}$Within column, values sharing no common letter were different ($P < 0.05$).

Table 2: Triiodothyronine (T_3) levels, and heart and liver ratio to broiler body weights according to the breeder lines and age of broilers

Lines	Age (d)	T_3	Heart / body ratio (%)	Liver / body ratio (%)
L	14	3.24 ± 0.37^a	0.45 ± 0.01^b	3.14 ± 0.09^b
	28	2.89 ± 0.71^a	0.34 ± 0.01^d	2.62 ± 0.05^c
	41	1.71 ± 0.20^b	0.29 ± 0.06^e	1.77 ± 0.04^d
E	14	3.73 ± 0.60^a	0.51 ± 0.01^a	3.56 ± 0.06^a
	28	2.80 ± 0.57^a	0.38 ± 0.01^c	2.62 ± 0.05^c
	41	1.56 ± 0.14^b	0.31 ± 0.01^e	1.94 ± 0.04^d
S	14	3.84 ± 0.58^a	0.52 ± 0.02^a	3.53 ± 0.09^a
	28	2.80 ± 0.50^a	0.37 ± 0.01^c	2.65 ± 0.04^c
	41	1.55 ± 0.16^b	0.30 ± 0.01^e	1.83 ± 0.04^d

$^{a, b, c, d, e}$Within column, values sharing no common letter were different ($P < 0.05$).

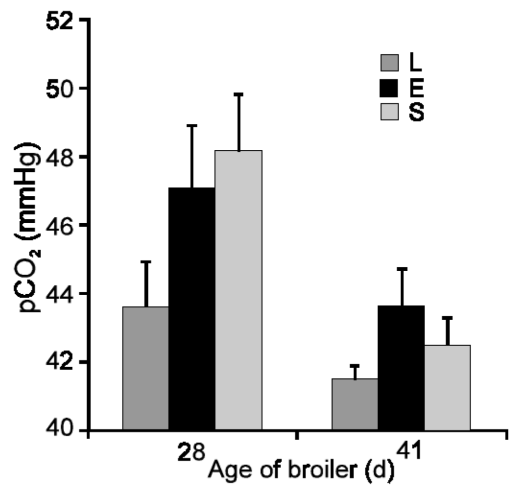

Fig. 1: Blood pCO_2 levels according to the age of broilers and breeder lines. Values sharing no common letters were different ($P < 0.05$)

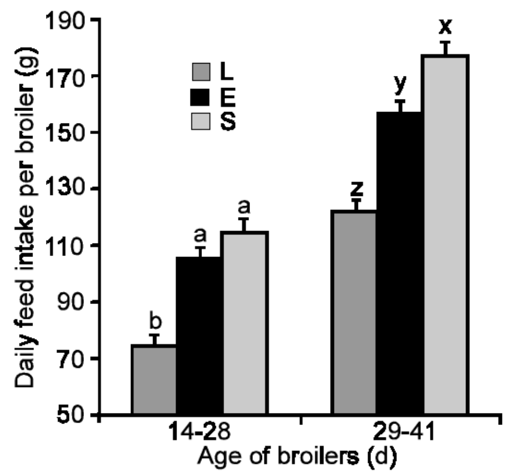

Fig. 2: Broiler feed intake according to the rearing period and breeder lines. Within each rearing period, values shearing no common letters were different ($P < 0.05$)

leads to an increase in the ratio of demand organs to that of supply organs such as heart and liver (Katanbaf *et al.*, 1988; Nestor *et al.*, 1995; Gavin and McDevitt, 1999). The liver and the heart play important roles in the metabolic activity of the whole organism. Our data show decreasing proportion of heart or liver to body weight with age in all lines. This is consistent with findings from previous studies (Gavin and McDevitt, 1999 and Havenstein *et al.*, 1994). This may mean that with increasing age, cardiac output or liver activity may slow down and therefore a concurrent reduction in metabolic rate and growth speed. Greenlees *et al.* (1989) reported an increased myocardial activity in young broilers that is no longer present in older broilers. The higher heart and liver proportions in the S and E lines than in the L line suggests greater cardiac output and liver activity to support the higher metabolic rate resulting in higher growth speed recorded for these lines at 14 and 28 d. The proportions of the organs at 41 d were not different between lines. It is especially important to note that dw E line can indeed perform comparatively well in growth rate as the standard S line since the proportions of heart and liver weights to body weights, blood pCO_2 and T_3 are virtually similar at all stages of growth.

It is concluded that growing broiler blood pCO_2, ratios of heart and liver to body weight are influenced by the age of broilers, the genetic lines and their interaction depending on the RG. But, T_3 levels and FCR were only related with broiler age. Broiler body weights are negatively correlated with RG, blood physiological parameters (pCO_2 and T_3) and supply organs (liver and heart). Also, the results from this study suggest that selection for fast growth improved broilers growth speed during the first 4 weeks of rearing. All these parameters, as a function of genetic lines or age of broilers, are closely linked to each other suggesting that they should be considered as tools of selection in order to improve broiler performance.

Acknowledgement

This work was supported by a European Community grant (QLRT-2000-1732). K.Tona was granted an OT fellowship from KU Leuven. Veerle Bruggeman was a postdoctoral fellow supported by the Fund for Scientific Research-Flanders (FWO-Vlaandere, Belgium).

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Abbreviation keys: T_3 = triiodothyronine, pCO_2 = Carbon dioxide partial pressure, RG = relative growth, IFI = individual broiler feed intake, FCR = feed conversion ratio

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