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Gas exchange, heat production and oxidation of fat in chicken embryos from a fast or slow growing line

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Abstract

The experiment comprised 48 chicken (*Gallus gallus*) embryos from a modern, fast growing line, Ross 308 (RO) and 48 from a slow growing line, Labresse (LA). The O_2 consumption and CO_2 production were measured in an open-air-circuit respiration unit, and heat production (HE) from embryos was calculated at an age of 10, 13, 16 and 19 days. Gas exchange was below 10 ml/h for RO and LA by an age of 10–13 days, increasing steeply to a "peak" on day 16 and then slowing down between 16 and 19 days. The pattern of curves for gas exchange was identical for RO and LA, but on a lower level for LA. HE followed the pattern of gas exchange, with a mean around 50 J/h on day 10, increasing to 528 (RO) and 402 (LA) J/h on day 19. The main source of HE was oxidized fat. In addition to respiration experiments chemical analyses were carried out on 60 eggs from RO and 60 from LA. Prior to chemical analyses the eggs were incubated for 7, 13 and 19 days. Since fat oxidation was the main energy fuel the content of fat in the eggs decreased by 2.0 (RO) and 1.6 g (LA), while protein content was fairly constant in each line. It is remarkable that the differences in heat production between chickens from fast and slow growing lines were already manifested during their embryonic development.

Keywords: Energy expenditure; Oxygen consumption; Carbon dioxide production; Fat oxidation; Embryo; Bird; Poultry

1. Introduction

In 1900, K.A. Hasselbalch, known for the Henderson–Hasselbalch equation, was the first to investigate gas exchange in chicken embryos. His measurements of CO_2 production during the incubation period showed a modest increase of CO_2 in the expired air within the first 10 days of embryonic life and then a rapid increase until about day 16 followed by a plateau until 1 day before hatching (Hasselbalch, 1900). The same pattern of gas exchange and consequently of heat production (HE) was measured by Romijn and Lokhorst (1960) followed by several more recent investigations (Tazawa, 1980; Geers et al., 1983; Ar et al., 1987; Tazawa et al., 1989; Nichelmann and Tzschentke, 2002).

Although the pattern of embryonic gas exchange and HE is similar in precocial birds the level of energy expenditure depends both on incubation conditions (French, 1997; Nichelmann and Tzschentke, 2002) and on bird species (Vleck and Vleck, 1987; Ancel and Visschedijk, 1993; Prinzinger and Dietz, 1995; Prinzinger et al., 1995; Gefen and Ar, 2001). Recently, Janke et al. (2004) demonstrated considerably higher HE values in broiler lines (White Plymouth Rock) Ross 308 and 508 compared with a layer line (White Leghorn) Lohmann. The differences in metabolic rate between embryos of broiler and layer genotypes may be related to different tissue composition (Pal et al., 2002).

It can be expected that different growth performance between different lines of broilers, or even between individuals, may already be expressed during embryonic life. Indeed, it has been demonstrated that different heat production, caused by different incubation temperatures during embryonic life (Geers et al., 1983) or by different genetic origin (Chwalibog et al., 2004), persisted during the early post-hatch period.

Considering that 1/3 of the broiler's life takes place during the prenatal phase quantitative determination of heat production in this phase may be a crucial parameter predicting metabolic rate and consequently, growth performance of chickens.

The aim of this investigation was to determine HE in embryos of slow and fast growing lines of chickens. Taking

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Table 1
Experimental design

	Start incubation			Measurements											
Day, no.	1	2	3	10	11	12	13	14	15	16	17	18	19	20	21
Group	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Age, days	1	1	1	10	10	10	13	13	13	16	16	16	19	19	19

Day of incubation and gas exchange measurements for three groups, each with 16 eggs from Ross and 16 from Labrasse, and age of embryos during measurements.

advantage of the indirect calorimetry technique it was also possible to evaluate amount of oxidized fat during embryonic development and to compare fat oxidation with changes in the fat content of eggs.

2. Materials and methods

The experiment comprised 48 embryos from a fast growing line, Ross 308 (RO) and 48 embryos from a slow growing line, Labresse (LA) of White Plymouth Rock. The fertilized eggs were immediately after delivery placed in a refrigerator (10 °C) and randomly distributed into three groups, each with 16 eggs from RO and 16 eggs from LA. On the following day, at 9.00 o'clock eggs from group 1 were moved from the refrigerator to an incubator with a constant temperature of 37.8 °C and a relative humidity of about 65%. The procedure was repeated on the second day with group 2 and on the third day with group 3, thereby a total of 48 eggs from RO and 48 from LA were incubated. Measurements of the gas exchange started when the embryos in each group were 10 days old and continued at age of 13, 16 and 19 days (Table 1). All eggs were candled before measurements of the gas exchange to ensure that the embryos were alive. Discarded eggs were replaced with eggs of the same age kept in the incubator as reserve.

The gas exchange was measured in an open-air-circuit respiration unit (Micro-Oxymax calorimeter from Columbus Instruments, Columbus, Ohio, USA). The unit contained four small chambers with a volume of 2000 cm^3, in which the temperature was kept constant at 37.8 °C as in the incubator. The oxygen consumption was measured according to the paramagnetic principle and the carbon dioxide production in accordance with the infrared principle. Prior to each measurement the gas sensors were calibrated against a gas mixture of known concentration and outdoor air.

Four eggs were placed in each respiration chambers and measured for 3 h from 9.00 to 12.00 followed by another group to be measured from 13.00 to 16.00. The eggs were after each measurement replaced in the incubator. The procedure was repeated on the following two days; thereby a total of 48 eggs from each line were measured. Assuming the time lag between morning and afternoon measurements, i.e. 5 h age difference between embryos has no effect on the final results the values were pooled. The actual data from each chamber were recalculated to standard conditions (STP: temperature 0 °C, pressure 760 mm Hg) and equally divided by the four embryos and the data are presented per embryo.

Heat production (HE) was calculated from O_2 consumption and CO_2 production in accordance with Brouwer (1965) and oxidation of carbohydrate (OXCHO) and fat (OXF) in accordance with Chwalibog et al. (1992). As nitrogen in urine (UN) cannot be measured it was omitted from the calculations.

$$\mathrm{HE,\ kJ} = 16.18 \times \mathrm{O_2,\ ml} + 5.02 \times \mathrm{CO_2,\ ml} - 5.99 \times \mathrm{UN,\ mg}$$

$$\mathrm{OXCHO,\ kJ} = (-2.968 \times \mathrm{O_2,\ ml} + 4.174 \times \mathrm{CO_2,\ ml} - 2.446 \times \mathrm{UN,\ mg}) \times 17.58$$

$$\mathrm{OXF,\ kJ} = (1.719 \times \mathrm{O_2,\ ml} - 1.719 \times \mathrm{CO_2,\ ml} - 1.963 \times \mathrm{UN,\ mg}) \times 39.76$$

In addition to the respiration experiment chemical analyses were carried out on 120 fertilized eggs, equally divided between the two lines. The eggs were placed in the incubator, and 20

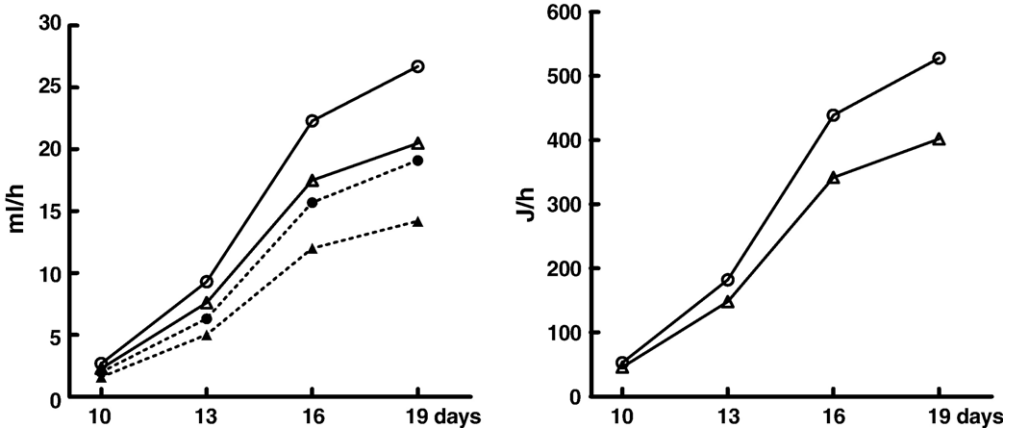

Fig. 1. Left: O_2 consumption ○ Ross, △ Labresse and CO_2 production ● Ross, ▲ Labrasse. Right: Heat production (HE) ○ Ross, △ Labresse during the incubation period. Mean values and standard deviations (for number of observations cf. Table 2).