Journal of Integrative Agriculture 2016, 15(10): 2336–2342

Available online at www.sciencedirect.com

ScienceDirect

RESEARCH ARTICLE

Effects of sustained cold and heat stress on energy intake, growth and mitochondrial function of broiler chickens

ZHANG Shao-shuai*, SU Hong-guang*, ZHOU Ying, LI Xiu-mei, FENG Jing-hai, ZHANG Min-hong

State Key Laboratory of Animal Nutrition, Institute of Animal Sciences, Chinese Academy of Agricultural Sciences, Beijing 100193, P.R.China

Abstract

To study the correlation of broiler chickens with energy intake, growth and mitochondrial function which exposed to sustained cold and heat stress and to find out the comfortable temperature, 288 broiler chickens (21-day with (748±26) g, 144 males and 144 females) were divided randomly into six temperature-controlled chambers. Each chamber contained six cages including eight AA broilers per cage, each cage as a repeat. After acclimation for one week (temperature, 21°C; relative humidity, 60%), the temperature of each chamber was adjusted (finished within 1 h) respectively to 10, 14, 18, 22, 26, or 30°C (RH, 60%) for a 14-day experimental period. After treatment, gross energy intake (GEI), metabolizable energy intake (MEI), the ratio of MEI/BW, metabolizability, average daily gain (ADG), the concentration of liver mitochondria protein and cytochrome c oxidase (CCO) were measured respectively. Our results confirmed that when the temperature over 26°C for 14 days, GEI, MEI and CCO activities were decreased significantly ($P<0.05$), but the concentration of liver mitochondria protein was increased and metabolizability of broilers was not influenced ($P>0.05$). Compared with treatment for 14 days, the ratio of MEI/body weight (BW) were also decreased when the temperature over 26°C after temperature stress for 7 days ($P<0.05$), meanwhile mitochondrial protein concentration was increased at 10°C and CCO activity was not affected ($P>0.05$). Additionally at 22°C, the ADG reached the maximal value. When kept in uncomfortable temperatures for a long time, the ADG and CCO activities of broiler were reduced, which was accompanied by mitochondrial hyperplasia. In summary, our study focused on the performance of broilers during sustained cold and heat environmental temperatures ranging from 10 to 30°C. From the point of view of energy utilization, moreover, 22 to 26°C is comfortable for 28–42 days broilers. And these could provide the theoretical basis on the high efficient production.

Keywords: broiler chicken, cytochrome c oxidase, energy intake, metabolizability, sustained cold and heat stress

1. Introduction

Mitochondria are the energy-producing organelles of eukaryotes, they generate ATP *via* the oxidative phosphorylation cycle, which consists of five complexes: complex I–IV and F_1F_O-ATP synthase (Elston *et al.* 1998; Noji and Yoshida 2001; Brière *et al.* 2004; Velours *et al.* 2009; Sharifabadi *et al.* 2012). Among the complexes comprising the oxidative phosphorylation cycle, cytochrome c oxidase (CCO; com-

Received 29 September, 2015 Accepted 3 February, 2016
ZHANG Shao-shuai, E-mail: zss9587@126.com;
SU Hong-guang, E-mail: hongguang.su@163.com;
Correspondence ZHANG Min-hong, E-mail: zmh66@126.com
* These authors contributed equally to this study.

doi: 10.1016/S2095-3119(15)61314-4

plex IV) is the last of the three proton-pumping complexes. This complex catalyzes the transfer of electrons from reduced cytochrome c to molecular oxygen, which is the final electron acceptor (Kadenbach *et al.* 2000; Popović *et al.* 2012; Sampedro-Piquero *et al.* 2013). Thus, mitochondrial protein concentration and CCO activity can be used as indicators of mitochondrial function (Li *et al.* 2001; Rajaei Sharifabadi *et al.* 2012), energy production, and energy utilization in animals.

Researchers have studied the effects of environmental temperature on the energy metabolism of hens (Barott and Pringle 1941, 1946; Wheelock *et al.* 2010; Dozier *et al.* 2011; Ferreira *et al.* 2011; Baumgard and Rhoads 2013). Yang *et al.* (2010) found that the function of the mitochondrial respiratory chain would be significantly induced when the broiler chickens under the acute heat stress. Li *et al.* (2001) studied the thermogenesis and thermoregulation of small mammals following cold acclimation for four weeks, then summaried the different cold adaptive thermogenesis at different geographical zones. Wang *et al.* (2006) investigated the effects of different photoperiods on the energy utilization of root voles, indicating that standard error (SD) alone is effective in inducing higher thermogenic capacities and energy intake coupled with lower body mass and body fat mass in root voles. Zhu *et al.* (2010) assessed the energy metabolism and thermogenesis of *Eothenomys miletus* following a 49-day cold treatment, their results showed that *E. miletus* enhanced thermogenic capacity and increased maintenance cost during cold acclimation, resulting in increased energy intake.

The above works show the changes of energy metabolism and the changes of mitochondrial respiratory chain under the acute heat stress or cold treatment in animals. However, there is little information on the effects of both high and low temperatures on an individual rather separately used in one study on the energy consumption and utilization of broiler chickens at the whole body and cellular levels. The objective of this study was to assess the energy intake, body weight, mitochondrial protein concentration, and CCO activity of broiler chickens exposed to 10 to 30°C for 14 days.

2. Materials and methods

2.1. Animals and management

In this study, 288 broiler chickens (144 males and 144 females; Arbor Acres, Beijing, China) at 21 days of age, were assigned to six environmental chambers. Each chamber contained six cages with eight birds (four males and four females) per cage (area of 0.8 m×0.75 m), and each cage as a replication. Birds were kept at 22°C and 60% relative humidity (RH) for one week. Following this acclimation period, the temperatures of each environmental chamber were respectively (within 1 h) set to 10, 14, 18, 22, 26, or 30°C while maintaining RH at 60% for 14 days (the accuracy of the environmental chamber was ±1°C for temperature and ±7% for RH). Body weight (BW) was measured on days 7 and 14 of the experimental period, without restriction of feed and water; feed intake was measured every day. The chickens had *ad libitum* access to feed and water during the experimental period and 24-h light cycles. Experimental diet was designed according to the NRC (1994) requirements. The composition and nutrient levels of the basal diets are shown in Table 1. Any aspect of the work covered in this study involved experimental animals has been conducted with the ethical approval of all relevant bodies.

2.2. Energy intake

Excreta were collected and weighed on days 7 and 14. Samples (approximately 100 g per cage) of feed and excreta were oven-dried at 60°C to constant weight. The caloric values of dry feed and excreta were determined with a Parr 6400 oxygen bomb calorimetry (Parr Instrument, USA). Energy intake expressed as gross energy intake (GEI), metabolizable energy intake (MEI), and apparent metabolizability of energy (hereafter referred to as metabolizability) was calculated according to the methods reported by Wang

Table 1 Composition and nutrient levels of the basal diet (as-fed basis) (%)

Items	Contents (%)
Ingredients	
Corn	56.51
Soybean meal	35.52
Soybean oil	4.50
NaCl	0.30
Limestone	1.00
$CaHPO_4$	1.78
DL-Met	0.11
Premix[1)]	0.28
Total	100.00
Nutrient levels[2)]	
Metabolizable energy (ME, MJ kg^{-1})	12.73
Crude protein (CP)	20.07
Ca	0.90
Available phosphorus (AP)	0.40
Lys	1.00
Met	0.42
Met+Cys	0.78

1) Premix provided the following per kg of the diet: VA 10 000 IU, VD_3 3 400 IU, VE 16 IU, VK_3 2.0 mg, VB_1 2.0 mg, VB_2 6.4 mg, VB_6 2.0 mg, VB_{12} 0.012 mg, pantothenic acid calcium 10 mg, nicotinic acid 26 mg, folic acid 1 mg, biotin 0.1 mg, choline 500 mg, Zn ($ZnSO_4 \cdot 7H_2O$) 40 mg, Fe ($FeSO_4 \cdot 7H_2O$) 80 mg, Cu ($CuSO_4 \cdot 5H_2O$) 8 mg, Mn ($MnSO_4 \cdot H_2O$) 80 mg, I (KI) 0.35 mg, and Se (Na_2SeO_3) 0.15 mg.

2) Calculated values.