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Research Report

Layer and broiler chicks exhibit similar hypothalamic expression of orexigenic neuropeptides but distinct expression of genes related to energy homeostasis and obesity

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ABSTRACT

Layer and broiler chickens demonstrate striking differences in body weight and body composition. However, the mechanism underlying such difference is elusive. Hypothalamus–pituitary–adrenal (HPA) axis regulates energy homeostasis and body size in mammals, but information in birds is scarce. Here we test the hypothesis that such breed difference is more associated with hypothalamic expression of genes related to HPA axis, rather than orexigenic neuropeptides. Broiler chicks exhibit significantly higher body weight and food intake at day (D) 7 posthatching, but the food intake relative to body weight gain was actually lower. No breed differences were observed for hypothalamic expression of neuropeptide Y (NPY), agouti-related protein (AGRP), proopiomelanocortin (POMC), orexin (ORX), leptin receptor (LEPR), acetyl-CoA carboxylase (ACC) or fatty acid synthase (FAS). However, broiler chicks expressed significantly higher glucocorticoid receptor (GR) mRNA ($P<0.05$) and protein ($P<0.01$) in hypothalamus compared to layer chicks, which is associated with lower corticotropin-releasing hormone (CRH) mRNA ($P<0.05$) yet higher accumulation of CRH peptide in hypothalamus, suggesting an augmented GR-mediated negative feedback regulation of CRH transcription and release in broiler chicks. Furthermore, fat mass and obesity associated (FTO) gene was also more highly expressed in hypothalamus of broiler chicks ($P<0.05$). These results suggest that the genes related to energy homeostasis and obesity, such as GR, CRH and FTO, rather than orexigenic

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Abbreviations: GH, growth hormone; SS, somatostatin; CNS, central nervous system; NPY, neuropeptide Y; ORX, orexin; AGRP, agouti-related protein; POMC, proopiomelanocortin; CRH, corticotropin releasing hormone; GLP-1, glucagon-like peptide-1; ACC, acetyl-CoA carboxylase; FAS, fatty acid synthase; HPA, hypothalamus–pituitary–adrenal; GR, glucocorticoid receptor; GCs, glucocoticoids; HSD, hydroxysteroid dehydrogenase; FTO, fat mass and obesity associated; ISH, in situ hybridization; LEPR, leptin receptor; FCR, feed conversion ratio; IN, infundibular nucleus; PHN, periventricular nucleus; LHA, lateral hypothalamic area; PVN, paraventricular nucleus; ICV, intracerebroventricular; nGRE, negative glucocorticoid response element; 20HSD, 20-hydroxysteroid dehydrogenase; ARC, arcuate nucleus; DMN, dorsomedial nucleus; VMN, ventromedial nucleus; ODN, oligonucleotide; RT, reverse transcription; M-MLV, Moloney Murine Leukemia Virus reverse transcriptase; NTC, No Template Controls; ECL, enhanced chemiluminescence; MGL, mean gray levels

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neuropeptides, are impacted by the genetic selection practices and play a role in breed-specific body weight setpoint regulation in the chicken.

1. Introduction

Layer and broiler chickens have been intensively selected over generations for egg and meat production respectively and demonstrate striking differences in body weight and body composition. Numerous studies have been carried out to discover corresponding differences in the regulatory mechanisms of growth, food intake, digestion, absorption and metabolism between these two breeds. However, none of the mechanisms seem to adequately explain the phenotypic differences between breeds.

Previous study indicated that somatotropic axis is more sensitive to the dietary regimen and the expression of growth hormone (GH) in pituitary and somatostatin (SS) in hypothalamus was determined by the diet rather than the genotype (Zhao et al., 2004). The difference in appetite does not provide satisfactory explanation either. Although the food consumption was two-fold greater in broiler than in layer breeder males, when food intake was normalized by body weight gain, the layers ate significantly more than the broilers, indicating the lower feed conversion rate or higher energy expenditure in layer chickens (Hocking et al., 1997; Swennen et al., 2007).

The central nervous system (CNS), especially the hypothalamus, is involved in the regulation of energy homeostasis and feeding behavior in mammals as well as in birds (Kuenzel et al., 1999; Morton et al., 2006). In mammals, a variety of orexigenic and anorexigenic neuropeptides have been identified (Leibowitz and Wortley, 2004; Bellinger and Langley-Evans, 2005). Orexigenic neuropeptides include neuropeptide Y (NPY), orexin (ORX), agouti-related protein (AGRP), etc., whereas anorexigenic neuropeptides include proopiomelanocortin (POMC), corticotropin releasing hormone (CRH), glucagon-like peptide-1 (GLP-1), etc. Similar neuronal network has been identified to regulate food intake and energy balance in avian species (Kuenzel, 1994; Richards, 2003) and it seems that different breeds of chickens respond differently to some (an) orexigenic neuropeptides. For example, AGRP stimulates feeding behavior in layer chicks, but not in broiler chicks (Tachibana et al., 2001). The anorexigenic effects of CRH are stronger in layer chicks than in broiler chicks (Tachibana et al., 2006). However, it is not clear whether the expression of endogenous neuropeptides is different between breeds under basal condition.

Hypothalamic fatty acid metabolism has recently been implicated to play a role in the regulation of food intake and energy homeostasis. Malonyl-CoA, an intermediate in the biosynthesis of fatty acids, appears to function in the hypothalamic energy-sensing system (Lane et al., 2005). Acetyl-CoA carboxylase (ACC) and fatty acid synthase (FAS), which catalyze the formation and utilization of malonyl-CoA respectively, are both involved in regulating feeding (Lopez et al., 2005). Hypothalamic ACC activation was shown to be involved in leptin's anorectic signaling pathway (Gao et al., 2007). Inhibition of FAS in the CNS reduces body weight by rapidly provoking a reduction in food intake and an increase in peripheral energy expenditure (Loftus et al., 2000; Tu et al., 2005). In birds, there are some evidences indicating a role of FAS in the regulation of food intake (Dridi et al., 2005; Dridi et al., 2006). However, it is to be determined whether hypothalamic expression of ACC and FAS exhibits breed specific pattern.

Hypothalamus–pituitary–adrenal (HPA) axis is involved in the stress-response and energy homeostasis (Tsigos and Chrousos, 2002; Adam and Epel, 2007; Nieuwenhuizen and Rutters, 2008). Hypothalamic glucocorticoid receptor (GR) mediates the negative feedback of glucocoticoids (GCs) to inhibit CRH secretion and thus attenuates the HPA activity to maintain energy homeostasis in mammals (Kellendonk et al., 2002). In the circulation, the GCs (mainly cortisol in mammals, corticosterone in birds) will be converted by hydroxysteroid dehydrogenase (HSD), 11HSD for mammals and 20HSD for birds in the brain (Kucka et al., 2006; Nieuwenhuizen and Rutters, 2008). The role of hypothalamic GR in birds is less intensively studied. Meat-type chicks demonstrated a blunted response of HPA axis to novel environment compared with layer-type chicks (Saito et al., 2005). However, it is unclear whether such difference was owing to the differences in the negative feedback mechanism of HPA axis at the level of hypothalamus.

The fat mass and obesity associated (FTO) gene identified in the genome-wide association study (Dina, 2008) is the first gene associated with common form of human obesity (Loos and Bouchard, 2008). Variants in the FTO gene are associated with body mass index in humans (Frayling et al., 2007; Dina et al., 2007) and fat deposition in pigs (Fontanesi et al., 2009). FTO mRNA was found to be abundantly expressed in the brain, particularly in hypothalamic nuclei regulating energy balance, and responded to nutritional manipulations such as feeding and fasting (Gerken et al., 2007; Fredriksson et al., 2008). The FTO gene is well conserved and found in a single copy in vertebrate species including fish and chicken (Fredriksson et al., 2008). However, it is not known whether FTO is expressed in chicken hypothalamus and how it is related to body size and body composition in the chicken.

Table 1 – Body weight, food intake and food intake rate of layer and broiler chickens.

	Body weight (g)	Food intake (g)	Feed conversion ratio
Layer	78.32 ± 0.93	16.24 ± 1.12	1.63 ± 0.10
Broiler	157.07 ± 1.98	39.10 ± 1.30	1.21 ± 0.05
P	<0.001	<0.001	<0.01

Data are shown as means ± S.E.M.