Keel-bone fractures are associated with bone quality differences in laying hens

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Abstract

This study aimed to investigate the relationship between bone quality in terms of metabolism, homeostasis of elements, bone mineral density (BMD), and microstructure and keel-bone fractures in laying hens (Gallus gallus domesticus). One hundred and twenty 17 week old Lohmann White laying hens with normal keel bones were individually housed in furnished cages for 25 weeks. Birds were then euthanased and dissected to assess keel-bone status at 42 weeks. Serum and keel-bone samples from normal keel (NK) and fractured keel (FK) hens were collected to determine the previously mentioned bone quality parameters. The results showed FK hens to have higher levels of the components of osteocalcin, greater alkaline phosphatase activity in serum and keel bones, and greater tartrate-resistant acid phosphatase (TRAP) activity in keel bones, compared to NK hens. Additionally, FK hens also had higher concentrations of Li, B, K, Cu, As, Se, Sn, Hg, and Pb, but lower concentrations of Na, P, and Ca. Moreover, FK hens showed decreased bone microstructural parameters including bone volume/tissue volume, trabecular number, degree of anisotropy, connectivity density, and BMD, but increased trabecular separation. Meanwhile, no differences were detected in serum TRAP activity, trabecular thickness, bone surface, or bone surface/bone volume. Results showed laying hens with keel-bone fractures to have differences in bone metabolism, elements of homeostasis, bone microstructure parameters, and BMD. These results suggest that keel-bone fractures may be associated with bone quality.

Keywords: animal welfare, bone metabolism, bone microstructure, bone mineral density, keel-bone fracture, laying hen

Introduction

In modern egg production systems where, as an alternative to conventional cages, laying hens (Gallus gallus domesticus) are housed in furnished cages or in non-cage systems, keel-bone fractures are one of the biggest threats to health and welfare (Riber et al. 2018). The keel is a structural bone that extends axially from the sternum over the midline in avian species, playing a vital role in flying and respiration (Casey-Trott et al. 2015). In addition to impinging upon bird behaviours, such as sitting, standing, sleeping, and perching (Nasr et al. 2012; Casey-Trott & Widowski 2016), numerous studies have reported that keel-bone fractures also led to a decrease in production performance and eggshell quality (Nasr et al. 2012; Rufener et al. 2012; Wei et al. 2020), as well as causing stress and inflammatory responses in laying hens (Wei et al. 2019).

Keel-bone fractures may also require a lengthy healing due to additional fractures occurring during the recovery period (Richards et al. 2011). Serum osteocalcin (OC) level and alkaline phosphatase (ALP) activity are crucial biological indexes, commonly used in the evaluation of osteoblast activity during bone remodeling in rats, sheep, and humans (Seibel 2006). Increase and decrease in OC was generally associated with an increase and decrease in osteogenesis, respectively. After complete recovery of damaged bone, the OC levels return to normal (Harris et al. 2001). Similarly, ALP activity in serum and bone increases as a result of bone damage and fracture healing (Hatayama et al. 2012; Kubo et al. 2012). Tartrate-resistant acid phosphatase (TRAP) is often used as an important indicator of osteoclast and macrophage activity (Schleicher et al. 2013). Decreased TRAP activity inhibits the ossification of cartilage tissue, while excessive activity can accelerate bone metabolism, which has been shown to cause osteoporosis in rats (Angel et al. 2000). Additionally, the activity of ALP and TRAP also reflects bone turnover levels during remodeling in laying hens fed omega-3 polyunsaturated fatty acid diets (Tarlton et al. 2013). Therefore, OC, ALP and TRAP are not only essential regulators of bone metabolism but may also be used as important predictors of bone health and quality in animals. Appropriate amounts of macro and trace minerals are known to be essential for maintaining the integrity of cell