



ASOCIACIÓN DE MÉDICOS VETERINARIOS ESPECIALISTAS EN AVES

Conferencia:	Manejo de densidad ósea en gallinas de postura
Fecha:	Viernes 13 de Mayo
Hora:	08.30 – 09.30 a.m.
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Take Home Message

Laying hens have three distinct types of bone tissues: Cortical and trabecular bone tissues are comprised of the outer “shell” and inner struts of bones, respectively, and give structural strength to the bone. Medullary bone is formed as the hen approaches the onset of egg production, and is intended to supplement dietary calcium supply for eggshell formation when dietary calcium is unavailable (eg. at night, when the bird’s digestive tract is empty). Medullary bone is mobilized and replaced on a daily basis as calcium supply and demand ebb and flow. Although medullary bone is intended to be the labile bone source of Ca, structural bone can also be mobilized and is not replaced as long as the hen is in egg production. A gradual loss of structural bone over time in laying hens can lead to osteoporosis (caged-layer fatigue; CLF). It is important to ensure that birds have appropriate levels of nutrients such as calcium, phosphorus and vitamin D. Many modern strains of laying hens have been selected for skeletal health as well as egg production and efficiency. However, CLF can still occur, and so it is important to understand how hens use their bones as a source of calcium to support eggshell formation. CLF rarely occurs in floor-housed birds, and recent research has shown that the ability to exercise will reduce the incidence of this problem. Feeding large particle calcium sources that are retained in the gizzard and gradually broken down provide calcium for an extended length of time, and reduce the need for the bird to mobilize bone calcium. Turning lights on in the barn for 1 hour in the middle of the night allows the birds to consume feed and replenish a supply of calcium available from the gut to be provided to the shell gland during peak eggshell formation during the night. CLF has many contributing factors, and requires a multi-faceted approach to solve.

Introduction

Laying hens face a set of challenges unique among livestock. With relatively small body reserves, they must sustain high levels of calcium output, and replenish these reserves on a daily basis. The demand for calcium for eggshell production is greatest at night, when there is minimal calcium coming from the digestive tract (Etches, 1987), and the hen must mobilize bone tissue to produce a high quality shell. Over time, laying hens may become prone to osteoporosis, which is the loss of structural bone tissue from the skeleton. More commonly known as caged-layer fatigue (CLF), osteoporosis can lead to hens going out of production, broken bones, and welfare problems (Webster, 2004). Gregory and Wilkins (1989) reported that in the UK, 29% of laying hens had broken bones before slaughter; Budgell and Silversides (2004) reported 19 to 22% of end-of-cycle commercial-strain laying hens had breaks following shipping as opposed to less than 4% in a non-selected Brown Leghorn strain.

Bone Development in the Pullet and Laying Hen

In order to equip the pullet to sustain high levels of egg production, proper skeletal development is essential. Longitudinal bone growth occurs as the pullet grows in size. Cartilage cells in the growth plates at the ends of the bones divide, resulting in increased bone length (Whitehead, 2004). At this point in the bird's life, two types of bone tissue are found in the long bones – cortical and trabecular. Cortical bone is the main, outer structural shell of the bone. Trabecular bone appears as struts or plates within the interior cavity of the bone (Figure 1).

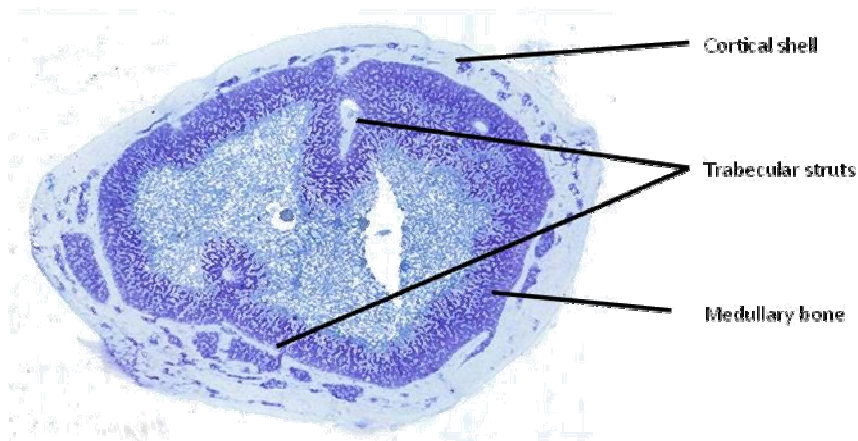


Figure 1. Histological section of the femur of a laying hen at first egg. The cortical shell is the outer structural bone tissue. The trabecular struts are interior structural bone, and lend strength and reduced weight to the bone. The medullary bone in the hen at first egg forms a discrete layer covering the structural bone tissue.



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As the pullet nears sexual maturity, a series of hormonal changes result in the growth plates at the ends of the bone ceasing to grow, and the growth plates become mineralized (Whitehead, 2004). Estrogen levels in the blood increase with the onset of sexual maturity (Beck and Hansen, 2004), and lengthening of the bones ceases, as well as deposition of structural bone. However, at this point, bone growth is not yet complete. In preparation for the increased calcium demand associated with egg production, pullets increase the diameter of many of the long bones by about 20% before the onset of lay (Riddell, 1992). This increased bone diameter allows a greater volume for deposition of medullary bone. This type of bone is not deposited until approximately 10 to 14 days prior to the first egg is laid (Hurwitz, 1964). Medullary bone is formed in female birds in response to the increasing levels of estrogen associated with the onset of sexual maturity (Miller, 1992), or the start of the breeding season in seasonal breeders. Medullary bone is deposited on the endosteal and trabecular surfaces within many of the bones of the skeleton, particularly the leg bones (Whitehead, 2004). Assuming proper pullet management, the pullet will have thick cortical and trabecular structures at the onset of sexual maturity. She will also have a substantial lining of medullary bone coating the surfaces of the structural bone within the medullary cavity of the bone (Figure 1). Medullary bone will continue to be deposited as long as the hen is producing high levels of estrogen. During a molt, estrogen levels drop, medullary bone is resorbed, and structural (cortical and trabecular) bone is replenished (Beck and Hansen, 2004). In summary, cortical and trabecular bone have primarily structural roles, whereas medullary bone is a labile source of Ca to support eggshell formation (Taylor and Moore, 1954; Hurwitz, 1965).

Much of the eggshell is deposited at night, when the hen is not consuming feed. As a continued supply of calcium is needed to form the shell, the hen mobilizes bone tissue to supply the calcium. Hens will preferentially increase feed consumption in the late afternoon on days when they are forming an eggshell in order to reduce the reliance on bone calcium. However, in many cases, this is not sufficient to eliminate the need for bone calcium to support eggshell formation. Osteoclasts are the cells responsible for mobilizing bone and releasing calcium to the bloodstream. In a young hen, the medullary bone is found in a relatively thick layer on cortical and structural bone surfaces, and the osteoclasts are likely to encounter only medullary bone. Following the egg being laid (typically in the morning), there is a period of time when demand for calcium is low because the shell for the next egg to be laid is not yet being formed. The hen also typically has access to feed at this point, and the medullary bone can be replaced.



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However, the medullary bone is not necessarily deposited in the exact place from which it was mobilized, and over time, the medullary bone becomes more diffuse throughout the marrow cavity of the bone. This leaves the surfaces of cortical and trabecular bone exposed to osteoclasts. Over time, the cortical and trabecular structures can be eroded, leading to thinner and therefore weaker structural bone tissue. Because structural bone is not replaced when estrogen levels in the blood are high, as long as the hen is laying eggs, this gradual erosion continues as long as the hen remains in production. This thinning of structural bone makes the hen susceptible to breaks (osteoporosis or CLF).

Implications – Preventative and corrective measures

The most important way to deal with CLF is to prevent it from happening in the first place. Lost structural bone will not be replaced as long as the hen is laying eggs, and so the only cure for CLF is a molt. Having individual hens in the flock undergoing a molt during the production phase reduces egg production, and therefore profitability of the flock. Clearly, taking steps to prevent CLF is necessary to maintain flock health, welfare and economic returns.

Variability in bone mineralization (Riczu et al, 2004) and susceptibility to bone breaks (Budgell and Silversides, 2004) are influenced by genetic factors. Although some evidence has been put forward that highly-selected strains of modern laying hens have increased susceptibility to bone fractures as compared to unselected lines (Budgell and Silversides, 2004), new evidence is beginning to emerge that hens can be selected for both high levels of egg production and strong bones (Fleming et al., 2006). Genetic selection may hold promise as a means to reduce the incidence of avian osteoporosis.

As the name implies, caged-layer fatigue affects hens housed in cages almost exclusively. The relatively small floor area allotted to the average laying hen precludes the bird getting much exercise. As is the case in humans, exercise appears to be essential in preventing osteoporosis in birds (Fleming et al. 1994; Knowles and Broom, 1990; Abrahamsson and Tauson, 1995). The problem is non-existent in properly nourished hens housed in extensive environments. Practical limitations on the large-scale commercial production of free-range or free run eggs have led to increased research activity in developing modified battery or colony cages that maintain the cleanliness and production efficiencies of caged layers, but still offer the birds opportunity to exercise (Jendral et al., 2008). In some cases, simply adding a perch to existing cages may allow sufficient exercise to occur to dramatically improve bone strength.



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Calcium is usually supplemented to layer diets either in the form of limestone or oystershell. Particle size may influence the availability of Ca from the gut over a longer period of time, since larger and less soluble Ca sources are gradually released from the gizzard, even when other components of the feed have passed through the digestive tract (Rao et al., 1992).

Scheideler (2004) suggested that for this reason, laying hen diets should contain at least 25% of the dietary calcium in the form of a large particle Ca source. We found that providing hens with supplemental calcium as 67% ground limestone + 33% oystershell (0.5 to 4 mm particle size) increased bone mineralization at 74 weeks of age (Saunders-Blades et al., 2009). The hens were fed diets adequate in all nutrients, including calcium. Similarly, Fleming et al. (1998) reported a decrease in bone loss when hens were fed a large particle calcium source. However, some reports suggest that particle size is most important when dietary Ca is low (Roland, 1986; Skrivan et al., 2010).

Midnight feeding involves providing one hour of light to the hens in the middle of the night. This allows the hens to consume feed, and replenish the supply of calcium coming from the digestive tract during shell formation, thus reducing the demand on bone calcium reserves (Keshavarz, 1998). Unpublished research in our lab indicates no difference in 24-hour feed intake with midnight feeding; the hens consume approximately 20% of their normal daily feed intake at night, and reduce their diurnal intake accordingly. The birds do not perceive the extra hour of light as the start of a new day, and photoschedules and diurnal patterns do not appear to be affected. Midnight feeding may also be of benefit in hot climates, where feed intake during the day may be limited (de Andrade et al, 1976) and therefore risk of caged-layer fatigue may be greater, because of the high temperatures.

Summary

The laying hen requires a large amount of calcium to support eggshell formation, both during a 24-hour period, and over the course of a production cycle. Although medullary bone is intended to supplement the dietary supply of calcium when the shell is being formed, excessive reliance on bone reserves of calcium can lead to osteoporosis (caged-layer fatigue). Good pullet management and feeding will allow the formation of optimal reserves of medullary bone. Although a decline in structural bone can be expected as high-producing hens age, proper supply of calcium in the diet, cage design, genetics, and patterns of feeding can all be used to reduce the risk of osteoporosis.





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References

- Abrahamsson, P. and R. Tauson. 1995. Aviary systems and conventional cages for laying hens. Effects on production, egg quality, health and bird location in three hybrids. *Acta Agric. Scand. Sect. A., Anim. Sci.* 45:191-203.
- Beck, M. M. and K. K. Hansen. 2004. Role of estrogen in avian osteoporosis. *Poult. Sci.* 83:200–206.
- Budgell, K. L. and F. G. Silversides. 2004. Bone breakage in three strains of end-of-lay hens. *Can. J. Anim. Sci.* 84: 745–747
- de Andrade, A. N., J. C. Rogler, and W. R. Featherston, 1976. Influence of constant elevated temperature and diet on egg production and shell quality. *Poult. Sci.* 55: 685–693.
- Etches, R. J. 1987. Calcium logistics in the laying hen. *J. Nutr.* 117: 619-628.
- Fleming, R. H., C. C. Whitehead, D. Alvey, N. G. Gregory, and L. J. Wilkins. 1994. Bone structure and breaking strength in laying hens housed in different husbandry systems. *Br. Poult. Sci.* 35:651-662.
- Fleming, R. H., H. A. McCormack and C. C. Whitehead. 1998. Bone structure and strength at different ages in laying hens and effects of dietary particulate limestone, vitamin K and ascorbic acid. *Br. Poult. Sci.* 39: 434-440.
- Fleming, R. H., H. A. McCormack , L. McTeir and C. C. Whitehead. 2006. Relationships between genetic, environmental and nutritional factors influencing osteoporosis in laying hens. *Br. Poult. Sci.* 47:742-755.
- Gregory, N. G. and L. J. Wilkins. 1989. Broken bones in domestic fowl: handling and processing damage in end-of-lay battery hens. *Br. Poult. Sci.* 30:555–562.
- Hurwitz, S. 1964. Calcium metabolism of pullets at the onset of egg production, as influenced by dietary calcium level. *Poult. Sci.*, 43:1462-1472.
- Jendral, M. J., D. R. Korver, J. S. Church and J. J. R. Feddes. 2008. Bone mineral density and breaking strength of White Leghorns housed in conventional, modified, and commercially available colony battery cages. *Poult. Sci.* 87:828-837.
- Keshavarz, K. 1998. Investigation on the possibility of reducing protein, phosphorus, and calcium requirements of laying hens by manipulation of time of access to these nutrients. *Poult. Sci.* 77:1320–1332.
- Knowles, T. G. and D. M. Broom. 1990. Limb bone strength and movement in laying hens from different housing systems. *Vet. Rec.*126: 354-356.



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- Miller, S. C. 1992. Calcium homeostasis and mineral turnover in the laying hen. Pages 61–75 in Bone Biology and Skeletal Disorders in Poultry. C. C. Whitehead, ed. Poultry Science Symposium No. 23. Carfax Publishing Co., Oxfordshire, UK.
- Rao, K. S., D.A. Ronald, J. L. Adams, and W. M. Durboraw. 1992. Improved limestone retention in the gizzard of commercial leghorn hens. J. Appl. Poult. Res. 1: 6-10.
- Riczu, C. M., J. L. Saunders-Blades, A. K. Yngvesson, F. E. Robinson, and D. R. Korver, 2004. End-of-cycle bone quality in white- and brown-egg laying hens. Poultry Sci., 83: 375-383.
- Riddell, C. 1992. Non-infections skeletal disorders of poultry: an overview. Bone Biology and Skeletal Disorders in Poultry. Poultry Science Symposium v 23. Carfax Publishing Company. Abingdon, UK.
- Roland, D.A. 1986. Eggshell quality. IV: Oyster shell versus limestone and the importance of particle size or solubility of calcium source. World's Poult. Sci. J., 42: 166-171.
- Saunders-Blades, J. L., J. L. Maclsaac, D. R. Korver, and D. M. Anderson. 2009. The effect of calcium source and particle size on the production performance and bone quality of laying hens. Poultry Science 88 :338–353.
- Scheideler, S.E. 2004. Calcium source, particle size and calcium level for 375 laying hen. In: proceedings of the Midwest Poultry Federation Convention. St Paul, MN, Midwest Poultry Federation.
- Skrivan, M., M. Marounek, , I. Bubancova, & M.Podsednicek. 2010 Influence of limestone particle size on performance and egg quality in laying hens aged 24-36 weeks and 56-68 weeks. Anim. Feed Sci. Technol. 158: 110-114.
- Taylor, T.G. and J. H. Moore, 1954. Skeletal depletion in hens laying on a low calcium diet. Br. J. Nutr. 8:112-124.
- Webster A. B. 2004. Welfare implications of avian osteoporosis. Poultry Sci. 83:184–192
- Whitehead, C. C. 2004. Overview of bone biology in the egg-laying hen. Poultry Sci., 83:193–199.