BREEDING STOCK AND BROILER

# LEG HEALTH

## A compendium of influencing factors

Aviagen®

# CONTENTS



Aviagen®

# 1

# OVERVIEW

## 1.1 ACTIONS THAT MAY PREVENT OR REDUCE THE INCIDENCE AND IMPACT LEVEL OF LEG HEALTH ISSUES

- Promote the correct physiological and skeletal development by balancing dietary levels of amino acids, calcium (Ca), phosphorous (P), and electrolytes.
- Optimize gut health to maximize absorption of available nutrients needed for physiological and skeletal development.
- Follow best practices for cleaning and disinfecting to reduce pathogen challenges between flocks and evaluate clean-out efficacy before future placements.
- Record all leg culls in the flock record sheet along with the cause and evaluate these for trends (changes).
- Breeding stock and broilers — achieve key body-weight standards and uniformity for age to promote proper physiological and skeletal development.
- Breeding stock — feed allocation levels should never be held constant or reduced, and minimum weekly feed increases should be given between 9 and 16 weeks of age, irrespective of body-weight gain.
- Breeding stock — introduce perches in rear and properly manage slats in production to promote better leg health.
- Consult a veterinarian and/or a technical manager for assistance if there are flock leg health concerns.

# 2

# INTRODUCTION

**Leg health is an important component of breeding stock and broiler welfare.**

If sufficiently severe, leg disorders may lead to mobility (i.e., walking, jumping, and mating) difficulties (***Appendix A***). Many leg health issues observed during rearing and production periods can be alleviated by employing appropriate management techniques.

Good leg health of breeding stock and broilers is key to achieving optimum flock performance and welfare. This document describes common leg health conditions observed and provides management advice and preventive strategies.

## 2.1 AVIAGEN'S RESPONSE TO LEG HEALTH ISSUES

Aviagen has shown that broiler leg health and weight have improved simultaneously (Kapell et al., 2012). The importance of leg health was recognized in Aviagen's breeding program strategy decades ago, with birds showing signs of impaired leg health excluded as selection candidates. Long-term trends showing decreases in the field prevalence of leg disorders have been achieved through a strong focus on accurately scoring selection candidates and a stringent exclusion policy of removing any candidate with clinical or subclinical leg defects.

In addition, predicted breeding values for candidates with nonclinical leg defects allow the identification of families prone to developing leg issues. Although the genetic basis (heritabilities) of leg health traits are low and their genetic correlations with body weight are unfavorably low to moderate, breeding strategies for simultaneous selection for live performance and leg health have been and continue to be effective. Broad breeding goals, including egg production, welfare, adaptability, livability, and reproductive fitness traits, are essential to achieve balanced progress in pedigree broiler lines. This approach continues to benefit the broiler industry globally.

# 3

# DESCRIPTION OF LEG HEALTH ISSUES

## 3.1 BIRD TYPES AFFECTED BY LEG HEALTH ISSUES

Although there is substantial variation in the incidence of leg disorders, evidence of leg health issues has been observed both in the field and in experimental trials in all modern commercial broiler genotypes, including slow-growing crosses. The risk of leg health issues is higher in poorly managed flocks. Regardless of genotype, early feed intake and the rate and uniformity of growth are key factors in optimizing physiological development and reducing the risk of leg health issues later in life.

## 3.2 WELFARE IMPLICATIONS

Animal welfare is a complex and multi-faceted subject with scientific, ethical, economic, cultural, social, religious, and political dimensions. It covers the physical and mental state of an animal in relation to the conditions in which it lives. It is important to understand that good welfare is more than just the absence of negative outcomes (e.g., mortality) and should include positive behaviors.

With this in mind, leg health is a crucial welfare area because it directly influences how the bird interacts with its surroundings. Good leg health contributes to good welfare as the bird can easily access food and water and naturally interact with its environment. Poor leg health can lead to poor welfare as mobility becomes compromised.

There is some heritability in welfare traits related to leg health, which allows breeding companies to continuously reduce the genetic propensity to express leg health issues in the field. However, the greatest influence comes through management, as the stockman directly influences the environment the bird interacts with.

## 3.3 BIRD HANDLING

All people caring for birds should be experienced and properly trained to understand the appropriate handling for the age, sex, and purpose of the bird. Clear guidelines on bird handling should be implemented, monitored, and reviewed regularly. Birds should be caught carefully and held in a way that minimizes/prevents distress, damage, and injury (e.g., bruising or dislocations), ensuring there are two points of contact on the bird: both legs, wings, or sides. Always follow national and local laws and regulations.

# 4

# COMMON LEG HEALTH ISSUES

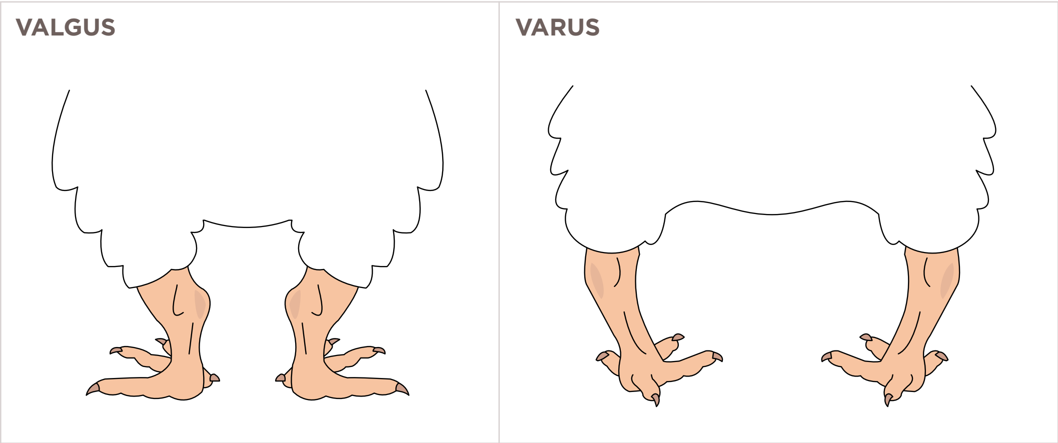
## 4.1 ANGULAR LEG DEFORMITIES, VALGUS-VARUS DEFORMITY (VVD)

The most common leg health issue in both breeding stock males and broilers, is angular leg deformities of varying degrees and incidence (***Figure 1***). Typically, what is observed is an outward (valgus, knock-knees, x-legs, twisted legs) or inward (varus, bow legs) deviation of the two bones meeting at the hock joint (tibiotarsus and tarsometatarsus). One or both legs can be affected.

Valgus-varus deformity of the hock joint is a leg deformity in broilers and male breeding stock. This condition often predisposes to slipped Achilles tendon in the affected leg. It is common to see submicroscopic lesions attributable to nutritional deficiencies; these deficiencies could be due to poor diet formulation or factors affecting feed intake or delivery of nutrients to the developing bone. Such lesions create irregularities in the distribution of blood vessel development around the growth plates of long bones, resulting in uneven bone growth and the development of the valgus or varus condition.

These deformities can occur at a higher frequency in breeding stock males which are below standard body weight for age during the first 12 weeks of life and/or where flock body-weight uniformity is poor. Please refer to **Section 8** for breeding stock management advice.

**Figure 1**
Intertarsal joints — valgus and varus.




## 4.2 TIBIAL DYSCHONDROPLASIA (TD)

Tibial dyschondroplasia is characterized by a cartilaginous plug in the proximal end of the tibiotarsus of growing chickens. Severe forms of this abnormal cartilage result in loss of mobility and, ultimately, reduced feed intake and body weight.

Tibial dyschondroplasia is most often observed after 20 days of age and can be seen secondary to earlier cases of rickets. Experimentally, lower calcium-to-phosphorus ratios (Ca:P) result in a higher incidence of TD. Along with a Ca:P imbalance (especially high P relative to Ca), high chloride (Cl) levels can also be a precursor, especially if there is high Cl, high P and low Ca.

Aviagen has selected against TD in broilers for decades to reduce the genetic propensity to express the condition in the field. However, as previously described, TD can be experimentally induced through dietary manipulations.

Tibial dyschondroplasia is confirmed upon post-mortem examination, where longitudinal slices of the proximal tibia head reveal a cartilaginous plug (***Figure 2***). Maintaining an optimal Ca:P ratio of 2 in juvenile birds is important for reducing the risk of TD.

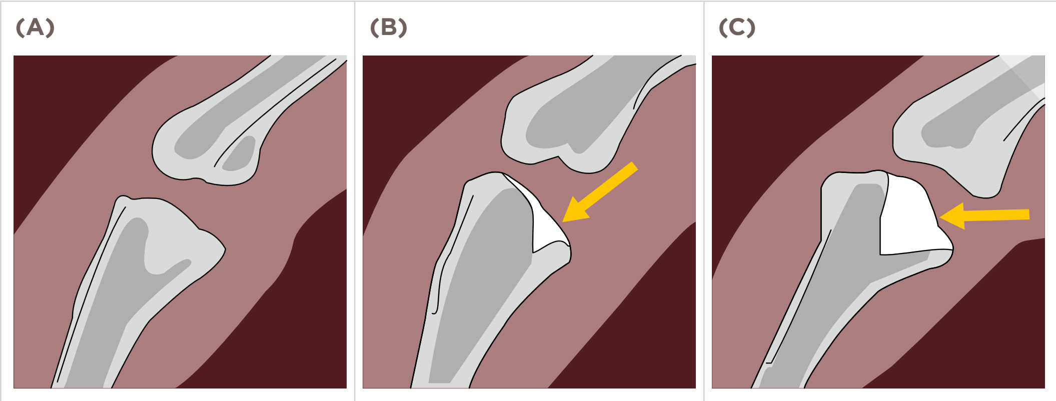



**Figure 2**
Illustrations of the scores for TD (yellow arrows): (A) no lesions, (B) moderate lesions, and (C) severe lesions.

## 4.3 RICKETS

Rickets is caused by either a mineral deficiency or imbalance in growing chickens. A Ca, P, or vitamin $D_3$ deficiency reduces skeletal calcification, impairing bone integrity and causing lameness. Seen mainly in young growing birds, rickets can also be caused by either a lack of vitamin $D_3$, which is required for absorption and utilization of Ca, or an excess of P.

Chicks fed lower than recommended Ca or vitamin $D_3$ levels are at greater risk for Ca rickets, which presents grossly different lesions than P-deficient rickets. Post-mortem examination reveals tibia slices with normal spongiosa (the area where new bone is deposited for growth) but an elongated growth plate (hypocalcemic rickets).

Chicks fed high Ca and low P levels show signs of hypophosphatemic (low levels of P in the blood) rickets and difficulty standing. Hypophosphatemic rickets shows a normal growth plate but a lengthened primary spongiosa (***Figure 3***).

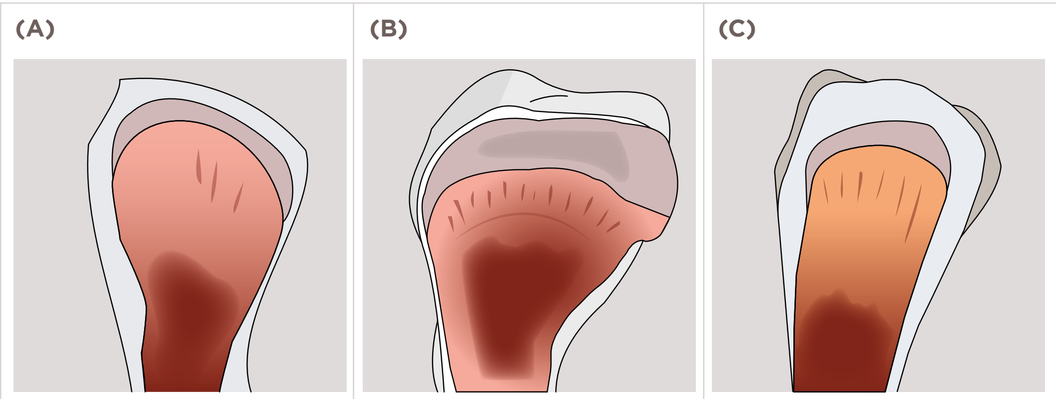



**Figure 3**
Illustrations of rickets: (A) no lesions, (B) hypocalcemic or vitamin $D_3$ deficiency, and (C) hypophosphatemic.

Rickets can be seen secondary to the malabsorption of nutrients (e.g., vitamin $D_3$). Destruction of vitamin $D_3$ can occur in the feed if antioxidants are not used. Runting and stunting syndrome (RSS), coccidiosis, and other major intestinal upsets or liver damage can cause malabsorption. In addition, aflatoxins or other mycotoxins — like ochratoxin, which may cause liver damage — can interfere with the metabolism of vitamin $D_3$, leading to poor leg health.

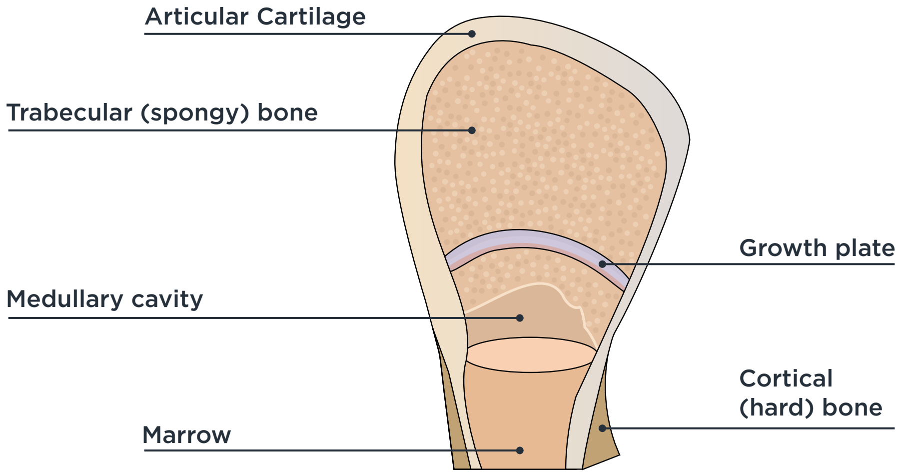
Treatment of rickets can be approached using products containing vitamin $D_3$ metabolites via water or feed. Depending on the vitamin $D_3$ metabolite, a faster utilization rate is achieved if a hydroxylation step is bypassed in the liver or kidney.

4.4

# LONG LEG BONE FRACTURES

Female breeding stock with poor early growth have an increased risk for bone fractures due to osteoporosis (Riddell et al., 1968). Breeder hens have two types of bone: cortical/trabecular (structural) and medullary (***Figure 4***). The structural bone maintains the physical integrity of the skeleton, and the medullary bone serves as a source of Ca for eggshell formation. A reduction in the quantity of structural bone weakens skeletal integrity, culminating in osteoporosis. Poor early skeletal frame development, a prolonged period of very high egg output, and low dietary Ca/vitamin $D_3$ can collectively become triggers for causing long leg bone fractures. Histopathology of fractured long bones (tibia and/or femur) often reveals substantial trabecular bone loss.

**Figure 4**
Structural components of the bone.




There is evidence that Ca pidolate improves Ca availability and absorption and is used to treat osteoporosis in humans. Calcium pidolate is also involved in protein biosynthesis and leads to the formation of amino acids, especially proline, hydroxyproline, and arginine, which are structural amino acids involved in collagen formation. Recent field studies suggest breeding stock leg health may improve when Ca pidolate is fed during rear.

An optimal dietary electrolyte balance (DEB = 200–250 mEq/kg) is also required for proper bone development and to maintain good litter quality.

Prevention of long bone fractures should focus on the following points:

- Early skeletal development (0–8 weeks of age).
- Early nutrition and body-weight gain.
- Feeding a pre-starter feed with adequate nutrient levels (refer to the ***Parent Stock Nutrient Specifications*** for more details).
- Improving body-weight uniformity prior to photostimulation.
- Avoid excessive body-weight gain and fleshing during the production period.
- Assessing feeding allocations and lighting programs.
- Ensuring precise Ca and P contributions from feed ingredients.
- Optimal Ca carbonate particle size.
    - Fine (300–700 microns) particle size in rearing diets.
    - Coarse (2000–3000 microns) in laying diets.
- Minimize natural bone loss in production.
    - Use a pre-breeder diet prior to photostimulation.
    - Supplementary Ca at the farm level during lay.
    - Supplemental vitamin $D_3$ or its metabolites.

## 4.5 CROOKED TOES (CT)

A deviation of the phalanges (curved or bent) in one or more of the toes, giving the foot a crab-like appearance, is defined as crooked toes (CT, ***Figure 5***). Crooked toes are not to be confused with curled toes, a rare condition caused by a riboflavin (vitamin $B_2$) deficiency. Using starter feeds with low levels of Ca elevates the risk of CT.

Another factor that can lead to a higher CT incidence in breeding stock males is a higher-than-recommended stocking density (3–4 males/m² or 2.7–3.6 ft²/bird).

Depending on the severity, CT can impact mobility and gait scores and may have welfare implications. Aviagen records the incidence of CT and includes it in the breeding goals to reduce the genetic propensity to develop the condition in the field.

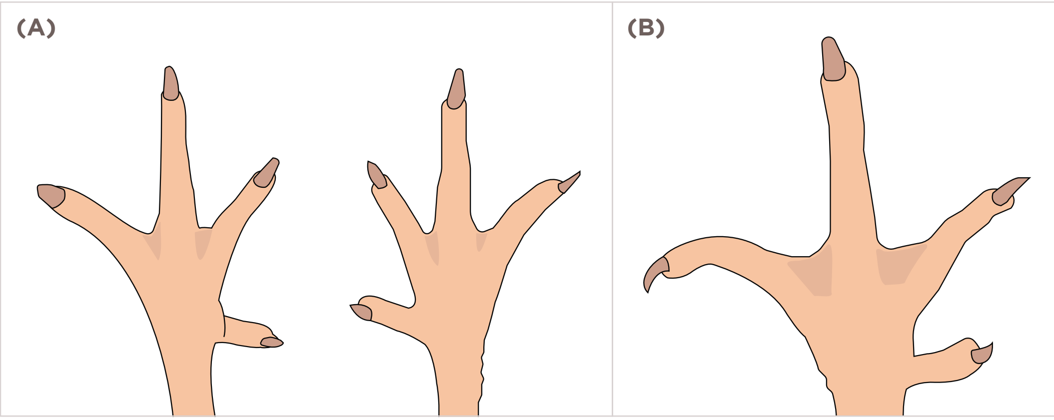



**Figure 5**
Illustrations of (A) healthy compared to CT (B).

## 4.6 RUPTURED TENDONS (RT)

Ruptured tendons (RT) have been diagnosed in breeding stock and occasionally in broilers for many years, with cases reported as far back as the 1950s. However, our understanding of the causes of RT has improved greatly since then. It is now recognized that several predisposing factors may contribute to RT, and when these factors are sufficient in number and severity, one or both gastrocnemius tendons rupture (***Figure 6***). It is also important to note that although RT most commonly occurs during early to mid-lay, tendon damage (i.e., loss of tensile strength) will most likely have occurred earlier in the bird's life (i.e., during rear).

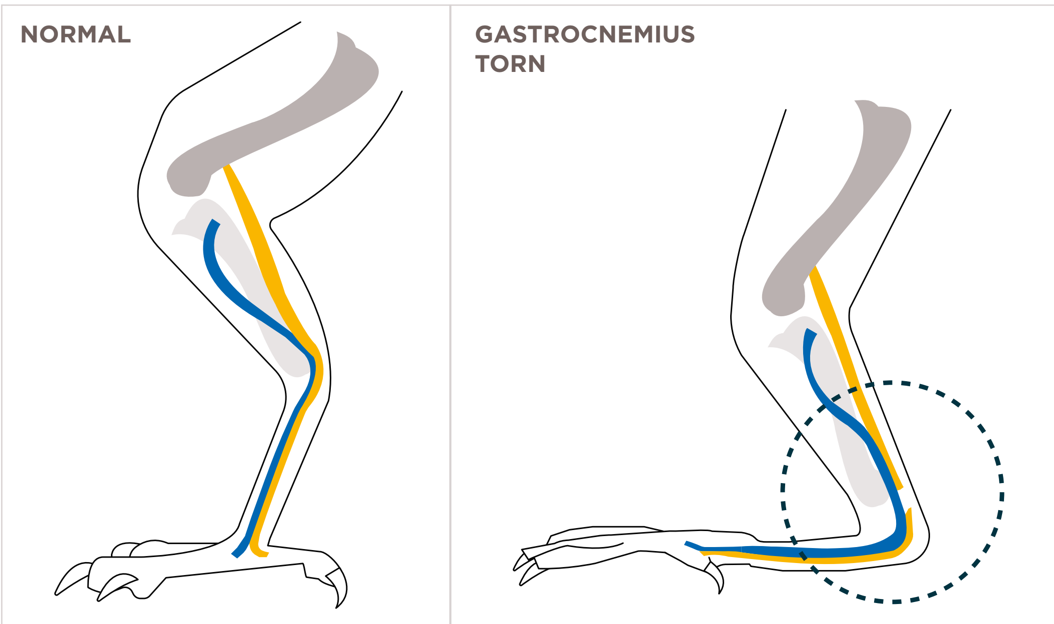



**Figure 6**
Diagram of a normal and ruptured gastrocnemius tendon.

Superficial digital flexor
Gastrocnemius
Femur
Tibia

There is little in scientific literature defining the causes of RT in poultry. However, several hypotheses have been proposed, including degenerative disease, infections from some avian reoviruses (ARVs), and some species of the bacterium *Staphylococcus*. It is suspected that the most common cause is from certain ARV genotypes (serotypes), which can cause viral arthritis (VA).

The two most common infectious causes of RT are ARVs and bacterial infections with *Staphylococcus*. ARVs should be ruled out as a contributor to RT during episodes of increased incidence. Live and inactivated ARV vaccines can help reduce the severity of an infection.

Some strains of *Staphylococcus* also produce protease enzymes that weaken the surrounding tissue, potentially resulting in subsequent tendon ruptures. Concurrent or previous infections from ARV and/or *Staphylococcus* should be ruled out as contributors to RT.

Non-infectious causes should be part of any RT investigation, including degenerative disease, overweight birds, improper slat management, improper feeder placement and height, and inadequate feed allocation increases (especially between 5 and 15 weeks of age). While the exact predisposing conditions that lead to degenerative damage (and eventual rupture) may be difficult to pinpoint, there is clear evidence that nutrient delivery to the tissue is critically important. Birds inadequately fed during rear are at a higher risk due to the lack of nutrient intake which is required for proper tendon growth and tensile strength. Diseases that impact intestinal health (e.g., coccidiosis, viral enteritis, and dysbacteriosis) may adversely affect nutrient absorption and delivery of nutrients to tendon tissue. As with VVD, nutrient intake in the first 12 weeks is extremely important for proper tendon development. Hence, there may be an indirect adverse impact on tendon health due to poor enteric health, which must be considered when investigating RT (refer to ***Section 5***).

## 4.7 MALE MUSCLE TEARS (MMT)

Despite a low occurrence, field cases of muscle-tear lesions in male breeding stock have been reported recently. Male muscle tears have primarily been seen in situations related to poor uniformity, such as ungraded flocks or where male and female comingling during rear is practiced. Male muscle tear-affected males are occasionally observed between 12 and 20 weeks of age. However, most cases occur from 17–20 weeks of age. The general observation is birds having an obscure gait described as "penguin walking" (standing upright like a penguin, ***Figure 7***). Upon necropsy, lesions show either unilateral or, more often, bilateral tearing of the distal quadriceps muscle (thigh muscles, ***Figure 8***). Upon histopathology, this appears as a pure muscle tear with no bacterial or viral involvement.

**Figure 7**
Male exhibiting a penguin-like posture.

**Figure 8**
Bilateral muscle tears of the distal quadriceps muscle (thigh muscles).

The exact etiology remains unknown, but inadequate nutrient intake needed for proper muscle and tendon development is suspected. The lesion appears to be exacerbated in males with a history of very low body weight at 4 weeks or birds reared under the recommended body-weight curves from 5–12 weeks of age. It most likely manifests at a later age when birds tend to put on additional weight, especially due to breast muscle growth; resulting in uneven pressure on the quadriceps muscle, which may cause it to tear.

## 4.8 BACTERIAL CHONDRONECROSIS WITH OSTEOMYELITIS (BCO) OR FEMORAL HEAD NECROSIS (FHN) AND VERTEBRAL OSTEOARTHRITIS (VOA)

Bacterial chondronecrosis with osteomyelitis, formally known as FHN, is a condition most often seen in birds under 20 weeks of age with immature and improperly calcified femoral heads. Most likely, there are tiny microfractures at the proximal end of the femur or femoral head, which is a high mechanical load-bearing joint in the chicken, especially in broilers. Bacteria can become established in the end arterioles, creating a bone infection (osteomyelitis). Premature cell death, autolysis of cartilage, and concurrent bacterial infection of bone and bone marrow can affect different parts of the skeletal system, although it is most frequently seen at the femoral head level. Many different species of bacteria have been isolated from BCO lesions, such as *Staphylococcus aureus (S. aureus)*, other *Staphylococcus* spp., pathogenic strains of *Enterococcus cecorum (E. cecorum), Enterococcus hirae (E. hirae), Enterococcus faecalis (E. faecalis)*, various *Streptococcus* spp., and *Escherichia coli (E. coli)*. Most of the bacteria mentioned above are considered normal inhabitants of a chicken's environment and are commonly found in poultry without any negative effects. However, they can also be opportunistic pathogens and may be implicated in joint, tendon and bone infections. *Staphylococcus aureus* may be associated with conditions such as tenosynovitis, arthritis, and BCO. Several *Staphylococcus* spp. exist, but *S. aureus* is the most clinically important. The probability of infection and whether a pathologic condition develops can depend on certain environmental influences, including:

- High levels of bacterial challenge.
- Injuries allowing a route of bacterial entry (including conditions that compromise the intestinal or respiratory lining, e.g., coccidiosis or respiratory viruses).
- Immunosuppression or distress.

If one or more of these risk factors are present in a flock, there can be an increased risk of bacterial problems. Insufficient feed allocations may increase the risk of the condition in rear.

In addition to BCO, bacterial infections in any leg joint, especially the hock joint, can be caused by the previously mentioned bacteria. However, *S. aureus, E. coli, and Enterococcus* spp. are the most common. In the last several years, *E. cecorum* and *E. faecalis* have been commonly isolated. *E. cecorum* can cause synovitis, septicemia (pericarditis/perihepatitis), and VOA. Most commonly seen in male birds, VOA infections cause pressure on the spinal column, leading to birds becoming lame due to paralysis.

## 4.9 AVIAN REOVIRUS (ARV)

Avian reoviruses can be divided into three functional groups based on their phenotypic characteristic (i.e., the pathology they cause).

***Viral arthritis*** usually results in leg problems involving the gastrocnemius tendon and, therefore, the hock joints with associated RT. The common strains are 1133, 1733, and 2177, in which one or sometimes two of these are included in a killed vaccine, and one would be included in a live vaccine. Bacteria, such as *Staphylococcus*, are often secondary invaders and can comingle with this infection. RT is usually observed after 17 weeks and within the first 6 weeks of introduction to the breeder lay house, specifically within the first 2 weeks of exposure to the breeder lay house and equipment (nests and slats), which coincides with photostimulation and an increase in body-weight gains. Early live vaccination is often recommended where there is a viral challenge and resulting problems.

***Runting and stunting syndrome (RSS)***, or early enteric issues, can result from an infection with ARVs, which seem to affect the intestinal tract, damaging villi and causing malabsorption of nutrients. However, reoviruses are not always involved in RSS. Rather, different enteric viruses are usually found in cases of RSS, and reovirus can be one of these (e.g., chicken parvovirus, chicken astrovirus, and rotavirus).

Reovirus was the original virus found to be associated with RSS and the reason why different strains are used in most killed reovirus vaccines.

In most commercial killed vaccines, one or two of these strains are included along with VA strains to give maternal antibody transfer (MAT) to the progeny to help them fight off early exposure during the first 2 weeks of life. Common examples of enteric strains of ARV include CO8, 2408 and SS412.

***Variant strains of avian reoviruses*** have caused issues in the last 10–15 years. These were first recognized in the USA but have now been identified in many other areas worldwide. Although these can be seen in breeding stock, they are most commonly observed in broilers. Variant strains of ARV are frequently recognized to start during the second week and develop thereafter as various leg issues; bird uniformity is often negatively impacted. Incidences of up to 20–30% of birds being affected have been reported. While the gastrocnemius tendon is often affected, the digital flexor tendon is more commonly involved. Many different structural leg abnormalities can be seen, and a few cases of neurologic involvement have occurred. These variant strains can be highly pathogenic and easily isolated. Dramatic immunologic responses, including very high enzyme-linked immunosorbent assay (ELISA) titers, can be observed as little as a few weeks after infection. These have also been implicated in occasional vertical transmission from parents (prior to this knowledge, ARV was not known to be vertically transmitted). Areas such as integrator complexes with viral challenges have resorted to using autogenous killed vaccines (customized vaccines) to protect progeny better. Currently, at least one commercial vaccine is available with variant genotypes included.

## 4.10 INFECTIOUS SYNOVITIS

Infectious synovitis in chickens is caused by *Mycoplasma synoviae* (MS), a small bacterium lacking a rigid cell wall. Although the incidence of MS has not increased, the prevalence has become more widespread, causing significant issues in many countries (Landman, 2014). The incidence of seropositivity in commercial egg layers may range from 70–90% (Landman, 2014). MS can cause a wide range of clinical problems, such as egg yolk peritonitis, egg production losses including smaller eggs, cracks and downgrades, eggshell apex abnormality (EAA) in commercial layers, and amyloid arthropathy (Landman et al., 2001). Hatchability can be affected in commercial layers and breeding stock (Stipkovits and Kempf, 1996). Although MS remains a silent infection and rarely affects breeding stock birds, MS synovitis is occasionally seen. The economic impact affecting the meat chicken industry is the result of vertical transmission of MS from parents to broiler progeny and a wide range of different manifestations of the infection, which may be MS strain-related: infectious synovitis (lameness and runts), chronic respiratory disease (CRD), decreased body-weight gain, and poorer feed conversion leading to increased medication costs and higher condemnation rates. Breeding stock flocks should be maintained free of MS.

# 5

# ENTERIC HEALTH AND LEG HEALTH

**Enteric health plays a major role in overall bird health and well-being; it drives digestion and absorption of nutrients for growth and represents one of the major immune interfaces preventing pathogens from entering the bird's body.**

Good enteric health relies on the interplay between the intestinal tissues, the intestinal microbiota, and the immune system within the intestinal tract (***Figure 9***). An imbalance in this relationship results in poor bird growth and development, directly impacting leg health. Good enteric health means there is optimal absorption of nutrients to meet the demands of the developing bone.

The first step is ensuring the correct development of intestinal tissues during the early life of the bird. The small intestine surface is covered by villi responsible for increasing the surface area for nutrient absorption; the longer these are, the greater the ability of the bird to absorb nutrients. During brooding, the villi develop rapidly, with the growth rate decreasing significantly after the first 7–10 days of life. Proper villi growth requires the provision of feed and water, correct temperatures, and a comfortable environment. Failure to provide the correct brooding conditions can result in poor villi development, leading to an intestinal tract with a reduced absorptive capacity. Lining the villi is a single layer of cells responsible for the uptake of digested nutrients for use by the bird. These cells are renewed frequently throughout the life of the bird. During the brooding period, these cells have a high metabolic and nutritional demand as they are growing rapidly; thus, optimal brooding conditions are essential for the establishment of these cells.

Within the intestinal tract is a large community of bacteria (known as the gut microbiota). These bacteria are essential for promoting and maintaining enteric health. However, there are normal members of this community which can cause disease should they pass from the intestinal tract into the bird's body (e.g., *E. cecorum*, *E. coli, S. aureus*). The cells lining the villi are held together by tight junctions, forming a barrier that prevents the bacteria passing from the intestinal tract into the intestinal tissues. This barrier can fail due to infection, heat stress, poor ingredient quality, imbalance in the intestinal microbiota, and mycotoxins. Following barrier failure, there is a reduction in nutrient uptake, which can lead to poor growth in the birds and bacterial overgrowth in the intestinal tract (dysbacteriosis). Furthermore, bacteria can then pass into the intestinal tissues, where they are/may be transported in the blood to the bones and joints, where they can cause disease. Therefore, ensuring good management, optimal nutrition, and disease control strategies are essential to maintain the integrity of this barrier.

Early feed intake is important to stimulate the immature intestinal tract to start producing the enzymes required to digest proteins, carbohydrates and lipids in the feed. It also promotes the expression of nutrient transporters along the small intestinal surface to ensure optimal uptake of digested nutrients. Another key link between early intestinal development and bone health is bone mineralization. At hatch, bones are non-mineralized, but the bone is rapidly mineralized during the first 2 weeks of life. The intestinal tract is most efficient at absorbing Ca during the first 2 weeks of life to meet this rapid development of bone and demand for Ca. Thus, promoting optimal nutrient intake and intestinal development during brooding is critical for the nutritional demands of early bone development.

Nutrient absorption along the gastrointestinal tract is also highly dependent upon the rate of passage of nutrients and the viscosity of the intestinal contents. A desirably slower feed passage rate through the intestinal tract increases the contact time between the digesta and the intestinal surface. However, should a slower rate of passage be accompanied by increased viscosity, there can be reduced nutrient uptake and an increased risk of bacterial overgrowth. The gizzard controls the rate of passage of feed into the small intestine; if the gizzard is not stimulated, its development can be impaired, leading to increased feed passage rates and reduced efficacy of nutrient uptake.

Focusing on early intestinal tract development is important for long-term enteric health, thus more beneficial for leg health. However, enteric health must be monitored and promoted throughout the life of the bird to reduce the risk of pathogens invading the bird's tissues, and ensure the bones receive all the nutrients they require.

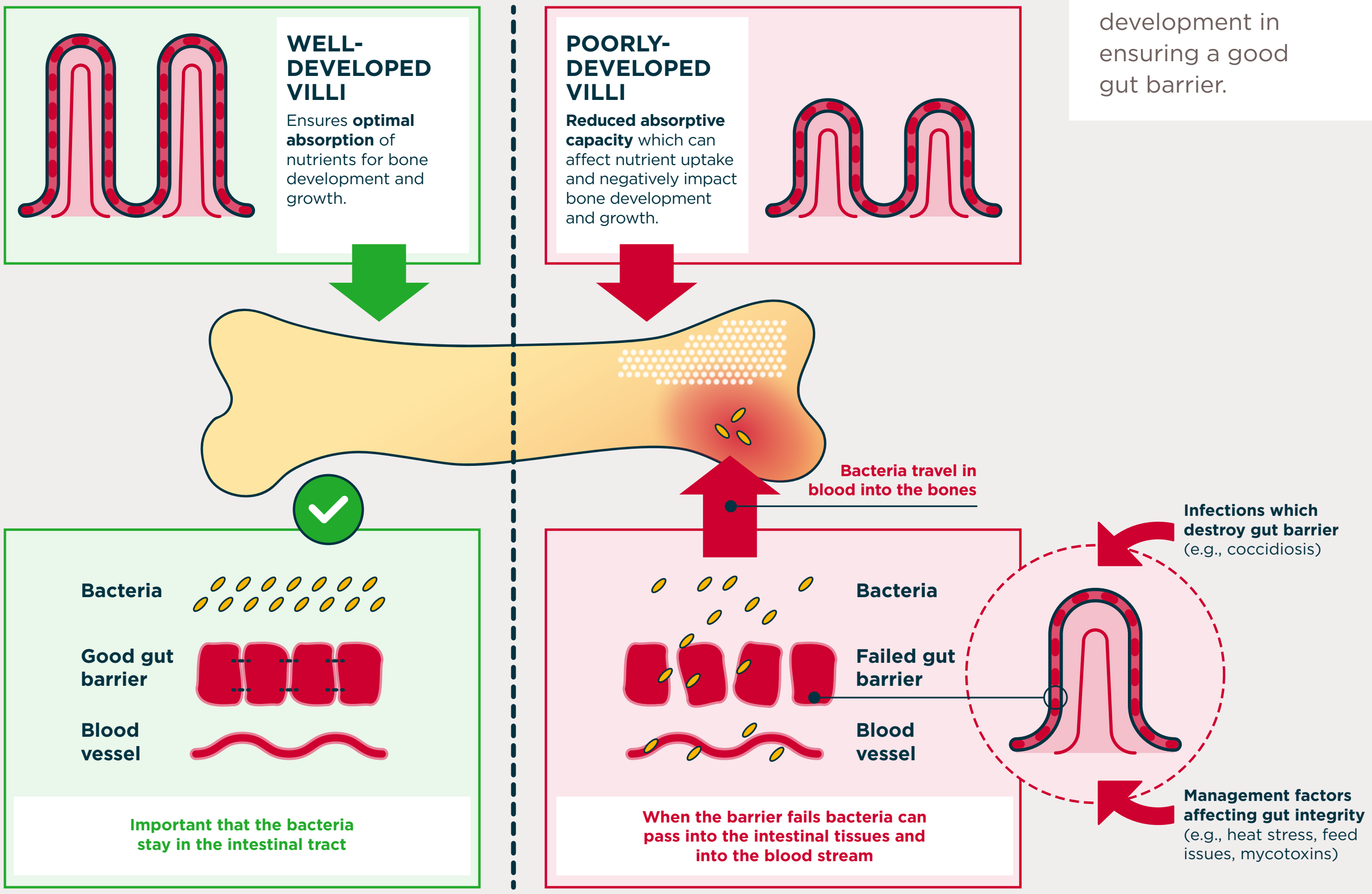



**Figure 9**
The role of villi development in ensuring a good gut barrier.

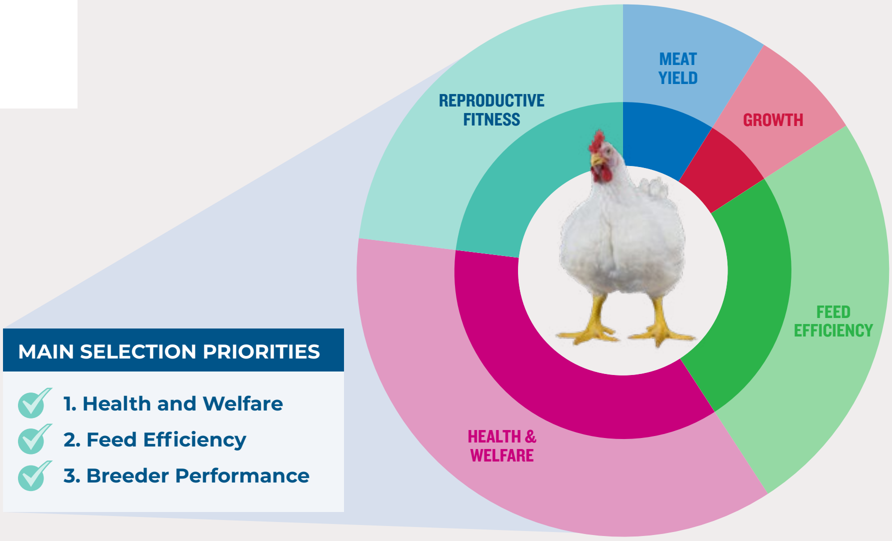
# 6

# SELECTION FOR IMPROVED LEG HEALTH

## Leg health improvement has been a focus of Aviagen's breeding goals for decades (Kapell et al., 2012).

Health and welfare characteristics take a significant share in the balanced selection process and are combined with biological efficiency and yield, as shown in ***Figure 10***.

**Figure 10**
Balanced broiler breeding goals.



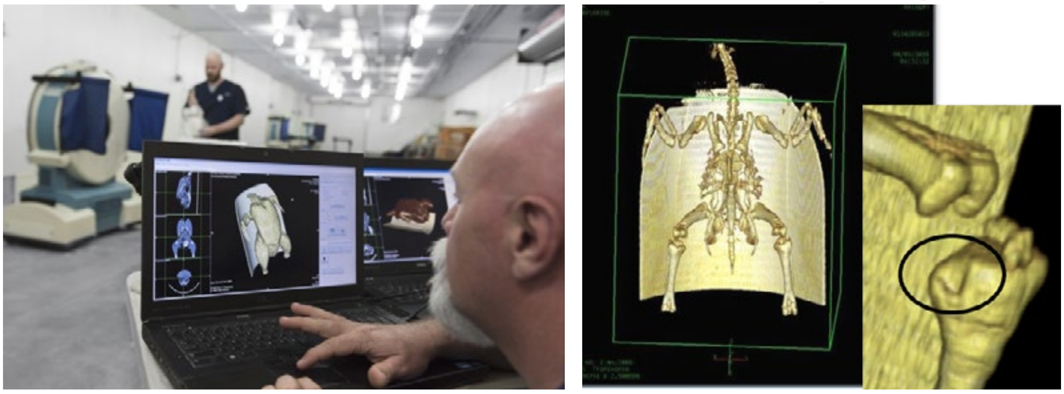

During the selection process, every pedigree selection candidate (male and female) goes through a very thorough physical examination to detect clinical and subclinical incidences of long bone deformities (LD), such as bowed legs seen with VVD, as well as CT and TD. During the selection process, the leg health assessment starts with a visual evaluation of the legs and feet to detect LD and CT, followed by an evaluation of walking ability using a gait scoring system (***Figure 11***).

**Figure 11**
Visual assessment of leg health and walking ability.

## SELECTION FOR IMPROVED LEG HEALTH

The visual assessment is complemented by a whole-body Computed Tomography scan (CT scan) to detect signs of clinical and sub-clinical TD using three-dimensional (3D) imaging, as depicted in ***Figure 12***.

**Figure 12**
Detection of TD using a CT scan.



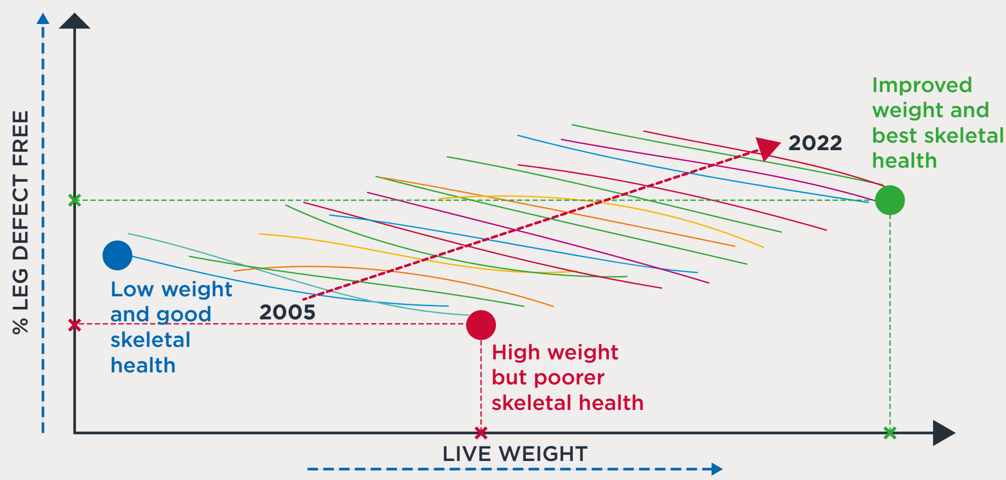
Aviagen operates on a zero-tolerance approach for clinical or sub-clinical incidences of skeletal deformities, meaning that for any bird to be selected as a breeder of the next generation, it must be free from any detectable structural issues.

The information collected during the selection process is used to predict the estimated breeding value (EBV). Estimated breeding values predict each selection candidate's genetic merit based on both the individual and their family (parents and siblings) information regarding all the traits in the breeding goal.

Leg health and production traits are typically antagonistically correlated, meaning that if selection focused only on production traits, leg health would be negatively impacted. This antagonism is resolved by having both traits in the breeding goal so that genetic progress in the desired direction can be achieved jointly.

***Figure 13*** shows the absence of leg defects as a function of live weight from 2005–2022. Each line in the graph represents the relationship between leg health (defined as % Leg Defect Free) and live weight. For example, the graph shows that in 2005, heavier birds tended to have poorer leg health, and lighter birds tended to have better leg health. Although the antagonism between both traits remains year after year, balanced selection has allowed for the selection of birds that improve the average of each trait simultaneously.

**Figure 13**
The absence of leg defects as a function of live weight.




As ***Figure 13*** shows, birds in 2022 had better genetic merit for both live weight and leg health compared to the birds in 2005. This principle also applies to the antagonisms between production traits and other fitness related traits such as CT, TD, and cardiovascular function.

Improving leg health and skeletal soundness is at the core of Aviagen's breeding strategy to ensure sustainable genetic progress across all aspects of bird performance. A broad and balanced breeding goal and continuous investment in research and development (R&D) to develop novel ways to assess selection candidates continue to improve health and welfare outcomes.

# 7

# INCUBATION AND LEG HEALTH

**Research trials in the USA, Turkey, and the Netherlands have investigated the impact of various aspects of incubation on bone development at different stages of embryo growth.**

They have demonstrated that hatchery and incubation conditions can affect bone growth and condition, although most of the trials have been done with broiler-hatching eggs rather than breeding stock.

For instance, when femoral head necrosis due to *S. aureus* is reported as an issue in an integration, chicks hatched from second-quality eggs (i.e., floor or soiled eggs) can show a higher incidence with chicks typically expressing problems within one week of hatching. The risk can be significantly reduced by not setting floor eggs or, if their use is unavoidable, segregating them into separate incubators and fumigating effectively with formaldehyde (where local laws and regulations permit) before the eggs are set and during hatch.

Low or high temperature and low or high oxygen levels in incubation can alter the weight or length of the leg bones, increase the incidence of TD and/or cause some asymmetry between the left and right legs. Any problems tend to be seen in day-old chicks or within normal broiler grow-out periods.

The trials reported in scientific literature have used a wide range of treatments and different ways of defining incubation temperature but confirm that leg health can be optimal when the eggshell temperature is held at 37.8–38.3 °C (100-101 °F) throughout incubation and when ventilation in the hatcher is adequate to maintain oxygen levels between 19 and 21%. None of the published trials have considered any possible impact on breeding stock.

8

# BREEDING STOCK MANAGEMENT AND LEG HEALTH

**Appropriate management practices, such as grading, extended lighting programs, and provision of an enhanced nutrient strategy when implemented during the rearing period, can help prevent the presence of leg health issues in late rear and production.**

During the rearing period, the strength and integrity of muscles, tendons, bones, and many other body components are determined by managing body weight to reach critical parameters in the bird's physiological development. The entire flock should achieve these developmental milestones uniformly and with the nutritional support necessary for each life stage.

The following subsections summarize the critical management practices that have the greatest impact on leg health. Please refer to the ***Parent Stock Management Handbook***, ***Parent Stock Nutrient Specifications*** and ***Parent Stock Performance Objectives*** for more detailed information.

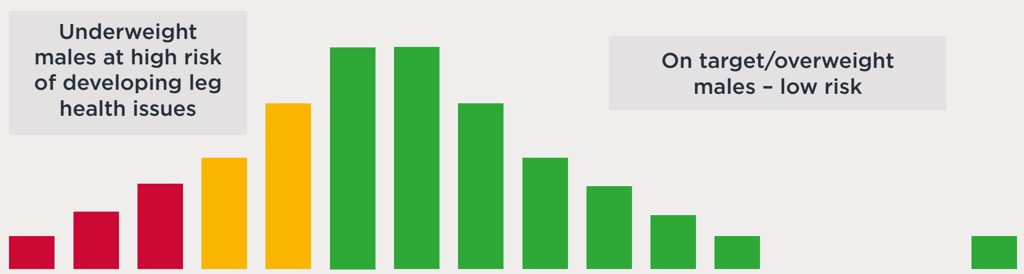
## 8.1 BREEDING STOCK BODY WEIGHT AND UNIFORMITY

Body-weight gain and uniformity are intrinsically linked in breeding stock management. Birds that are not receiving required nutrients will:

- Be underweight.
- Have impaired early physiological development.
- Have a greater risk of leg health issues in production.

A flock with average body weight on the standard for age has birds below and above the standard body-weight profile. Compared to the standard, underweight birds are at a higher risk of developing problems related to leg health. The greater the variation, the greater the number and potential severity of issues (***Figure 14***).

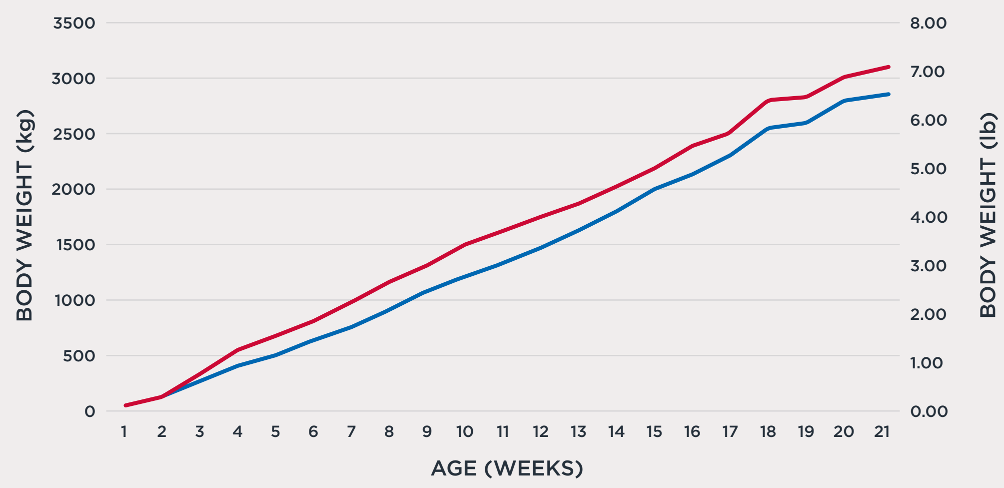
**Figure 14**
Poor uniformity affects the incidence and severity of leg health issues.




Where uniformity is poor, targeting a heavier body weight may be necessary to ensure all birds in the population achieve the standard. This higher body weight should be achieved gradually from 3 weeks of age for the greatest benefit by adding approximately 6% from 4 weeks and gradually returning to body-weight standard after 10 weeks.

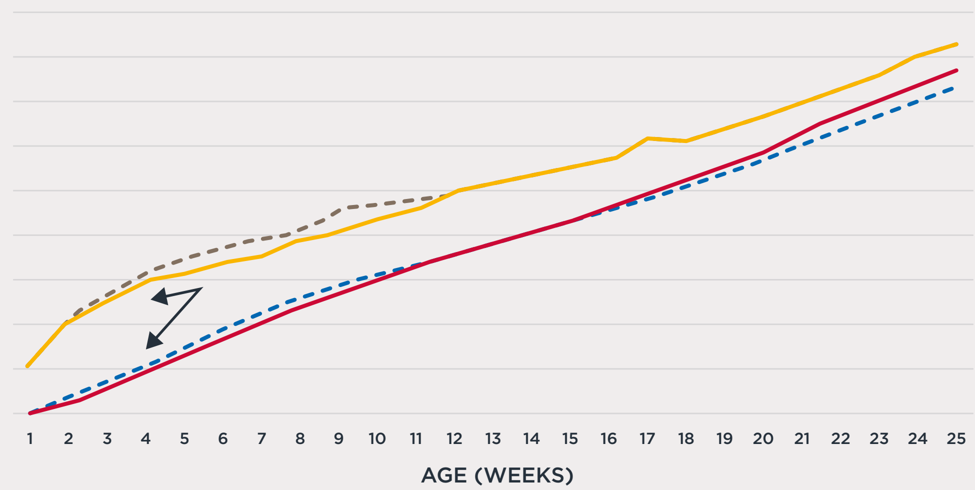
***Figure 15*** compares two body-weight profiles: a control and one where the body weight was kept 20% below the standard. The lighter body-weight group demonstrated a higher incidence of leg defects when compared to the control group.

**Figure 15**
Trial summary of males reared on a 20% lighter body-weight profile, which exhibited a higher incidence of leg defects at 19 weeks compared to the control.




The importance of optimal nutrition, correct feed allocation, and uniform feed distribution should not be underestimated in their effects on achieving both early and subsequent late-rear body weight. ***Figure 16*** illustrates data from a commercial breeding stock flock where male feed intake at 4 weeks was 10% behind the standard (feed volumes should always be determined by energy intake). As a result, weekly body-weight gains were not achieved during this critical period.

**Figure 16**
Commercial breeding stock flock — Influence of early feed intake on body weight (arrows = 4-week body weight and feed intake).




## 8.2 BREEDING STOCK EARLY FEED INTAKE

Sufficient early feed intake helps birds achieve weekly body-weight standards to optimize gut development, skeletal development, and other physiological targets.

Listed below are key management factors to optimize this early development of feed intake (refer to Aviagen poster: ***The First 24 Hours***).

- Optimize environmental conditions during the brooding period.
- Add feed, little and often, to encourage activity and feed uptake.
- Assess crop fill to achieve >75% by 2 hours, and if not, take corrective action to achieve >80% at 8 hours.
- Ensure 7-day body weights are on or above standard. Where this is not achieved at 7 days (e.g., young source flocks), follow the recommendations in **Section 8.3.**

# 8.3 LIGHTING PROFILE AND AD-LIBITUM FEEDING

As recommended in the ***Parent Stock Management Handbook***, a constant 8 hours of daylength should be reached by 10 days of age. However, farms with a history of underweight-for-age flocks should consider extending the period taken to reach 8 hours of daylength by more gradually decreasing the hours of daylength, allowing birds more time to consume feed (***Figure 17*** and ***Figure 18***). Ensure feed is readily available until 8 hours is reached, but avoid excessive feed, which could be lost in the litter, causing uniformity issues.

| | |
|---|---|
| **Considerations** | • Mixed-sex housing (separate sex pens within the same house): Reach 8 hours by 18 days at the latest.<br>• Male-only housing: Reach 8 hours by 26 days at the latest. |

**Figure 17**
An example of an extended lighting program where flocks have been underweight.

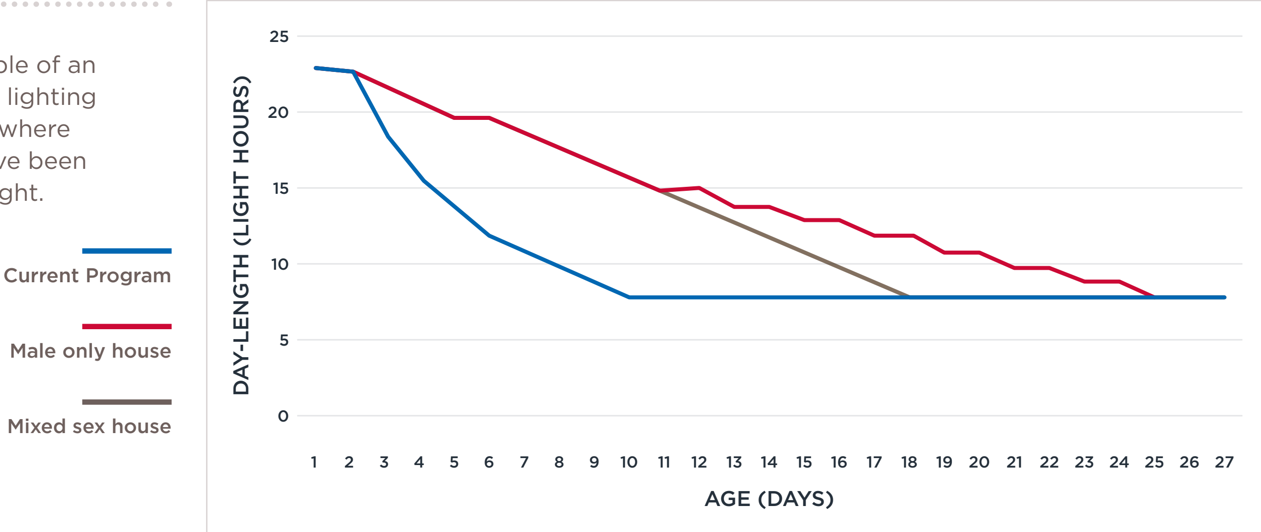
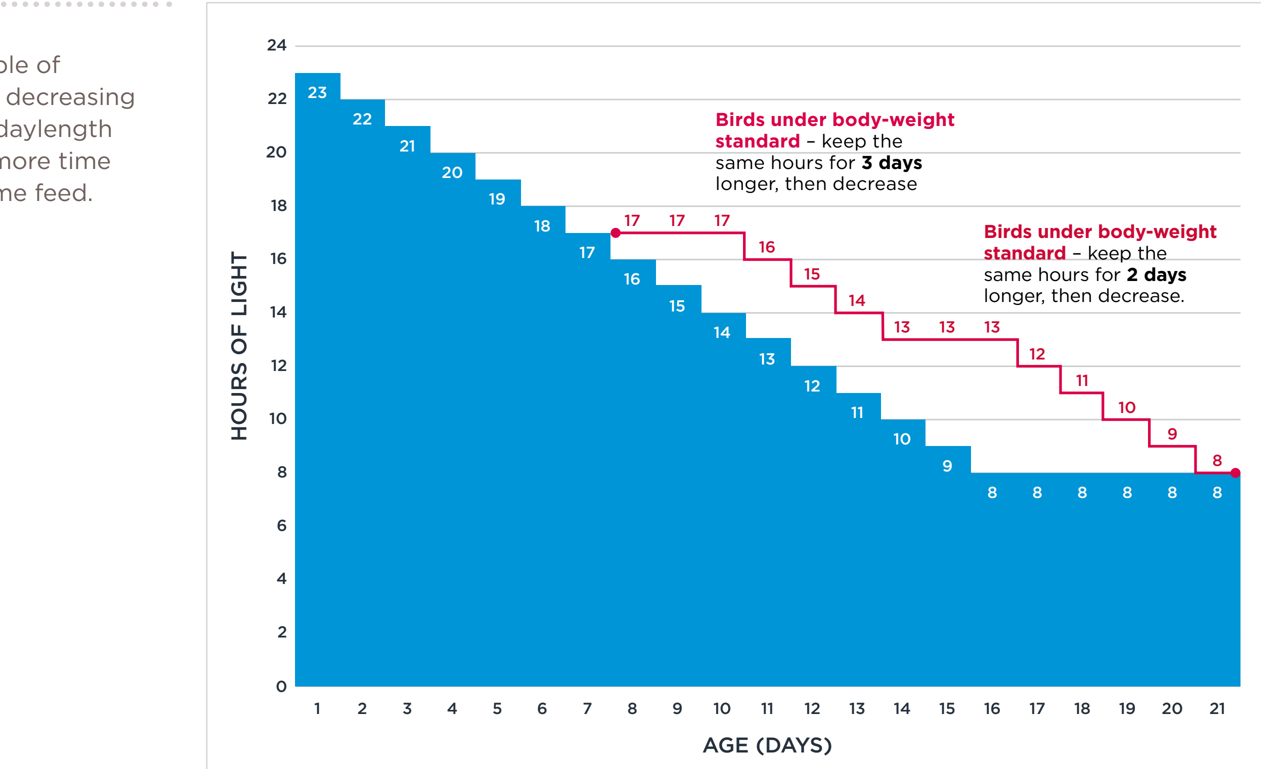



**Figure 18**
An example of gradually decreasing hours of daylength to allow more time to consume feed.



## 8.4 GRADING TO MANAGE UNIFORMITY

A uniform flock responds uniformly to feed increases. Grading at 4 weeks of age helps maintain good flock uniformity. All graded populations should return to the body-weight standard by 10 weeks of age. Flocks that are overweight at 10 weeks should achieve the targeted incremental weight gains; provide the appropriate feed to maintain the heavier profile. Post-grade feed management must be optimized for individual populations to avoid a reduction in nutrient intake.

Grading involves a sample weighing (minimum of 2% or 50 birds, whichever is greater) and calculating the coefficient of variation (CV%) to determine the band limits (weight ranges) required for grading and the weight limit thresholds for these. Weight limit thresholds for bands depend on whether pen sizes are fixed or can be adjusted. ***Table 1*** shows the grading thresholds when using CV% and whether a two or three-way grade is required (please refer to the ***Parent Stock Management Handbook*** for more detailed information).

**Table 1**
Grading cut-offs when using CV%.

| Flock Uniformity CV% | 2 or 3-way grade | Percentage in Each Population after Grading | | |
|---|---|---|---|---|
| | | Light (%) | Normal (%) | Heavy (%) |
| **8-10** | 2-way grade | 20 | ~ 80 (78-82) | 0 |
| **10-12** | 3-way grade | 22-25 | ~ 70 (66-73) | 5-9 |
| **>12** | 3-way grade | 28-30 | ~ 58 (55-60) | 12-15 |

## 8.5 BREEDING STOCK FEEDING AND BODY-WEIGHT MANAGEMENT

To ensure birds receive sufficient nutrients, provide dietary nutrient levels recommended by Aviagen (refer to the ***Parent Stock Nutrient Specifications*** for more detailed information) and allocate feed to achieve or slightly exceed the recommended profile in rear. Weekly incremental body-weight gain targets should always be as per the standard, even if birds are overweight, and feed allocations should never be kept the same for longer than one week. Birds should not fall below the recommended body-weight standard. Feed allocations should never be held or reduced during rear.

Feeding during the first 3 weeks should be managed to prevent feed build-up on the chick paper and in the litter. Built-up feed can lead to an artificial restriction as this feed is not available for consumption or considered in the daily allocation.

The critical period for weekly feed increases is 9–16 weeks of age. During this period, it is recommended that the birds receive continual increases in weekly feed amounts for optimal physiological development.

Importantly, this increase in feed (and incremental increases in body weight) should be maintained even if birds exceed the recommended body-weight standard. Leg issues have been reduced in locations where this approach has been implemented.

## 8.6 BREEDING STOCK FEEDING SPACE

Providing adequate feeding space ensures birds have uniform access to feed and uniform feed distribution of the total feed volume. Where feeding space is considerably greater than the recommendation (***Table 2***), achieving even feed distribution becomes more difficult throughout the house due to insufficient volumes.

**Table 2** Recommended feeding space for males and females.

| MALES | | | FEMALES | | |
|---|---|---|---|---|---|
| **Age (days)** | **Track Feeder cm (in)** | **Pan Feeder cm (in)** | **Age (days)** | **Track Feeder cm (in)** | **Pan Feeder cm (in)** |
| 0-35 days | 5 (2) | 5 (2) | 0-35 days | 5 (2) | 4 (2) |
| 36-70 days | 10 (4) | 9 (3.5) | 36-70 days | 10 (4) | 8 (3) |
| 71-105 days | 15 (6) | 11 (4) | 71-105 days | 15 (6) | 10 (4) |

## 8.7 PERCH PROVISIONS FOR BREEDING STOCK

Perch provision encourages activity and builds musculature and leg strength. Although research into this area is limited, it is widely agreed that perch type and height are both important considerations. It has been shown that adult broiler breeders prefer to roost on elevated slats rather than perches (Mens and van Emous, 2022).

If using perches, allow access from 28 days and provide 3 cm (1.2 in) per bird. Ensure that at least 20% of the population can roost at one time.

## 8.8 WATER AVAILABILITY

Water is critical in transporting nutrients, removing waste products, and maintaining body temperature. Furthermore, water is also an essential nutrient in its own right to ensure optimal biological function and the growth and maintenance of body tissues. Therefore, it is essential that water is both available and accessible to the birds to achieve a feed-to-water ratio of 1.6–2.0. The birds require more water if the feed form is easily detectable in the crop. To ensure the birds consume adequate water, water pressure and drinker line height must be assessed for the bird's age, development, and environmental conditions in conjunction with regular crop assessment.

Optimal water supply is important for birds' growth and welfare. Birds should always have unlimited access to clean, fresh, good-quality drinking water ***(****refer to* ***Aviagen Brief: Water Line Sanitation*** *and* ***Aviagen Best Practice on the Farm: Alternative Water Disinfection Methods during Production)***. However, when water intake is naturally low — during the dark period when birds are inactive, for example — control of the water supply may help to reduce unnecessary water leakage. Any control of water should be managed with care; there must be no restriction on the volume of water required for birds to grow and a balance must be found between growth and welfare.

# 9

# BROILER MANAGEMENT AND LEG HEALTH

**The following subsections summarize the critical management practices that most impact leg health in broilers.**

More detailed information is available in the ***Broiler Management Handbook, Nutrient Specifications*** and ***Performance Objectives.***

## 9.1 BROILER EARLY GROWTH

Final body-weight performance positively correlates with early growth rate; ensuring chicks get off to a good start is critical. Chicks with a poor start are more susceptible to disease challenges, compromised weight gain, environmental stressors, and poorer breast meat quality. Feeding recommended nutrient levels during the brooding period supports good early growth and physiological development, ensuring body-weight objectives and good health and welfare are achieved.

## 9.2 BROILER LIGHTING PROGRAMS

The provision of continuous or near-continuous lighting programs can negatively affect the health and welfare of broilers. It has been shown that prolonged lighting programs (>20 hours of light) result in increased skeletal abnormalities in broilers (van Der Pol et al., 2015). At placement, provide 23 hours of light with a minimum 30–40 lux (2.7–3.7 fc) intensity and 1 hour of dark (less than 0.4 lux [0.04 fc]) to help the chicks adapt to the new environment and encourage feed and water intake. Gradually reach 4-6 hours of darkness by 7 days, preferring to have the same on-time every day, to optimize behaviors associated with food and water intake, optimize biological performance, and enhance bird welfare.. It should be noted that lighting programs for broilers should be implemented to comply with local laws and regulations. It should also be noted that abrupt changes to the lighting program should be avoided.

## 9.3 LIGHT INTENSITY FOR BROILERS

A dark period is considered a period where light intensity is less than 0.4 lux (0.04 fc). Light intensity encourages bird activity, especially feeding activity, ensuring biological targets are reached. A minimum light intensity of 30–40 lux (3–4 fc) from 0–7 days optimizes access to the feed and water to ensure the early body-weight standard is met, followed by a reduction to 20 lux (2 fc) at around day 20. The actual light intensity minimum should follow local laws and regulations.

## 9.4 PERCH PROVISIONS FOR BROILERS

Perching on an elevated surface is an essential behavior in most avian species; roosting kept birds out of reach of predators before domestication. This behavior is still observed in broilers. Although providing perches is not generally a common practice, many researchers have investigated the optimal perch provision and design to promote bird use, which is adequate for their age and physiological development. It has been identified by Bist et al., (2023) that the provision of perches to broilers allows birds to select an area with lower temperatures away from the warmer litter material, which may improve performance and welfare by relieving heat stress and leg issues.

The provision of platform perches encourages perching behavior in broilers (Kiyma et al., 2016); this is a result of better support for the body of the broiler and the reduced need to balance compared to the bar perch design. Continuous movement through activity on and off a perch positively impacts tibia weights in broilers (Turkyilimaz et al., 2020) and increases muscle mass around the leg bone (Pedersen et al., 2020).

## 9.5 BROILER FEEDER PROVISION AND HEIGHT

Providing the correct feeding space for broilers is essential to allow uniform and easy access to feed (***Table 3***). Any delay in reaching feeders due to insufficient space can increase stress in the flock and negatively affect broiler leg health and welfare.

**Table 3**
Feeding space per bird for different feeder types.

| Feeder Type | Feeding Space |
|---|---|
| Pan feeders | 45-80 birds per pan (the lower ratio for bigger birds [>3.5 kg/7.7 lb]) |
| Flat chain/auger* | 2.5 cm/bird (1 in/bird) |
| Tube feeders | 70 birds/tube (for a 38 cm/15 in diameter feeder) |

**Birds fed on both sides of the track.*

Appropriate feeder height at every age is also important for encouraging activity that aids in strengthening bone and leg muscles (***Figure 19***). The base of the pan should be aligned with the breast of the broiler to prevent birds from resting close to the feeders and thus affecting access for other birds.

**Figure 19**
The correct height of feeders for broilers.

# 10

# INTERNAL TRIALS

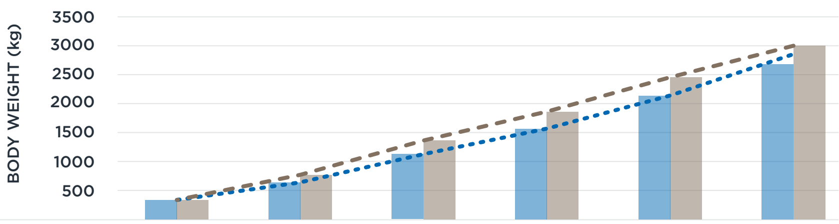
## It has been proposed that rearing males on a lighter-than-recommended body-weight profile may have a negative impact on the incidence of angular leg deformities (i.e., VVD).

It has been further suggested that feeding a pre-starter diet may help alleviate the effect of angular leg deformities by providing added nutrients (a higher energy level and amino acids) needed during the first weeks of growth and bone development. A study explored the influence of both following a lighter body-weight profile when compared to Aviagen's standard advice and providing a pre-starter diet on the performance of breeding stock males.

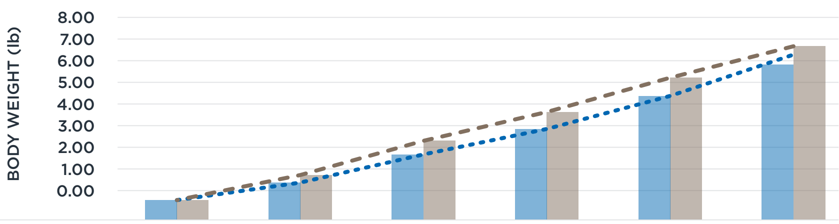
Birds were reared on either the Standard or a Light profile (up to 20% lighter than Standard). Each body-weight profile was divided into two groups and fed either a pre-starter diet for the first 2 weeks followed by a starter diet for up to 4 weeks or only a starter diet from 0 to 4 weeks. Males were fed a common grower (5-15 weeks) and a pre-breeder diet (16-22 weeks). The Light body-weight profile was established to be 120, 285, and 330 g (0.26, 0.63, and 0.73 lb) lighter at 4, 8, and 12 weeks, respectively. The study evaluated individual body weight and shank length with a leg health evaluation at 22 weeks.

At 4 weeks, males raised on the Standard profile were approximately 19% heavier than those raised on the Light profile, while at 20 weeks, the difference was approximately 350 g (0.77 lb) or 12% (***Figure 20***).

**Figure 20**
Standard and Light body-weight profiles of males in rear.




| AGE (WEEKS) | 2 | 4 | 8 | 12 | 16 | 20 |
|---|---|---|---|---|---|---|
| Actual Light | 286 | 593 | 1100 | 1499 | 2103 | 2653 |
| Actual Standard | 300 | 729 | 1344 | 1828 | 2441 | 3012 |
| Target Light | 272 | 635 | 1134 | 1588 | 2132 | 2858 |
| Target Standard | 320 | 755 | 1420 | 1920 | 2420 | 3035 |




| AGE (WEEKS) | 2 | 4 | 8 | 12 | 16 | 20 |
|---|---|---|---|---|---|---|
| Actual Light | 0.63 | 1.31 | 2.42 | 3.30 | 4.64 | 5.85 |
| Actual Standard | 0.66 | 1.61 | 2.96 | 4.03 | 5.38 | 6.64 |
| Target Light | 0.60 | 1.40 | 2.50 | 3.50 | 4.70 | 6.30 |
| Target Standard | 0.71 | 1.66 | 3.13 | 4.23 | 5.34 | 6.69 |

The effect of feeding a pre-starter diet on body weight and shank length was minimal. The main impact on shank length was from the body-weight profile, with birds reared on the Standard profile having longer shanks than those grown on the Light profile (***Figure 21***). At 20 weeks, the shank length in the Standard male group was approximately 5% (approximately 5 mm or 0.20 in) longer than the Light group.

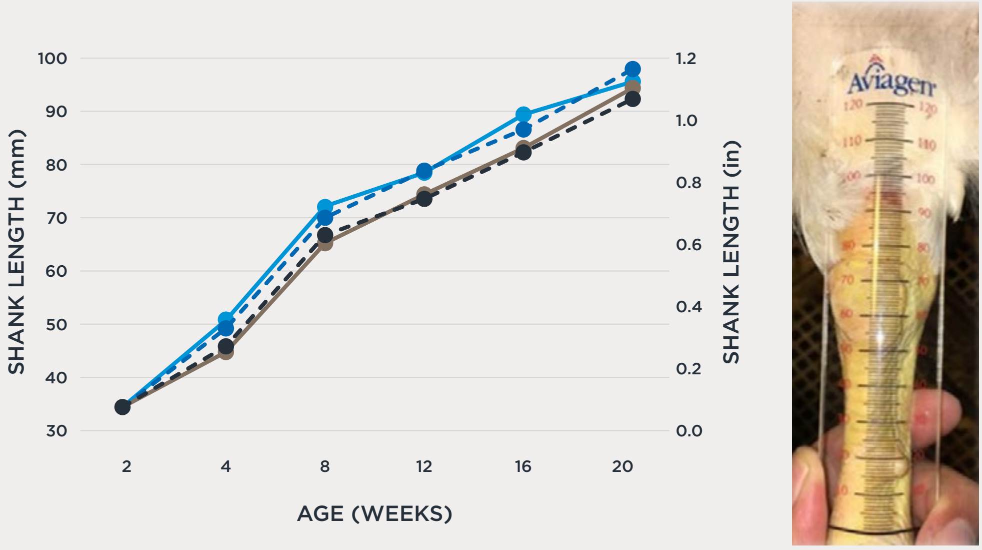
**Figure 21**
Shank length of breeding stock males reared on either Standard or a Light body-weight profile fed with or without a pre-starter diet.

Prestarter light

Prestarter standard

Starter light

Starter standard

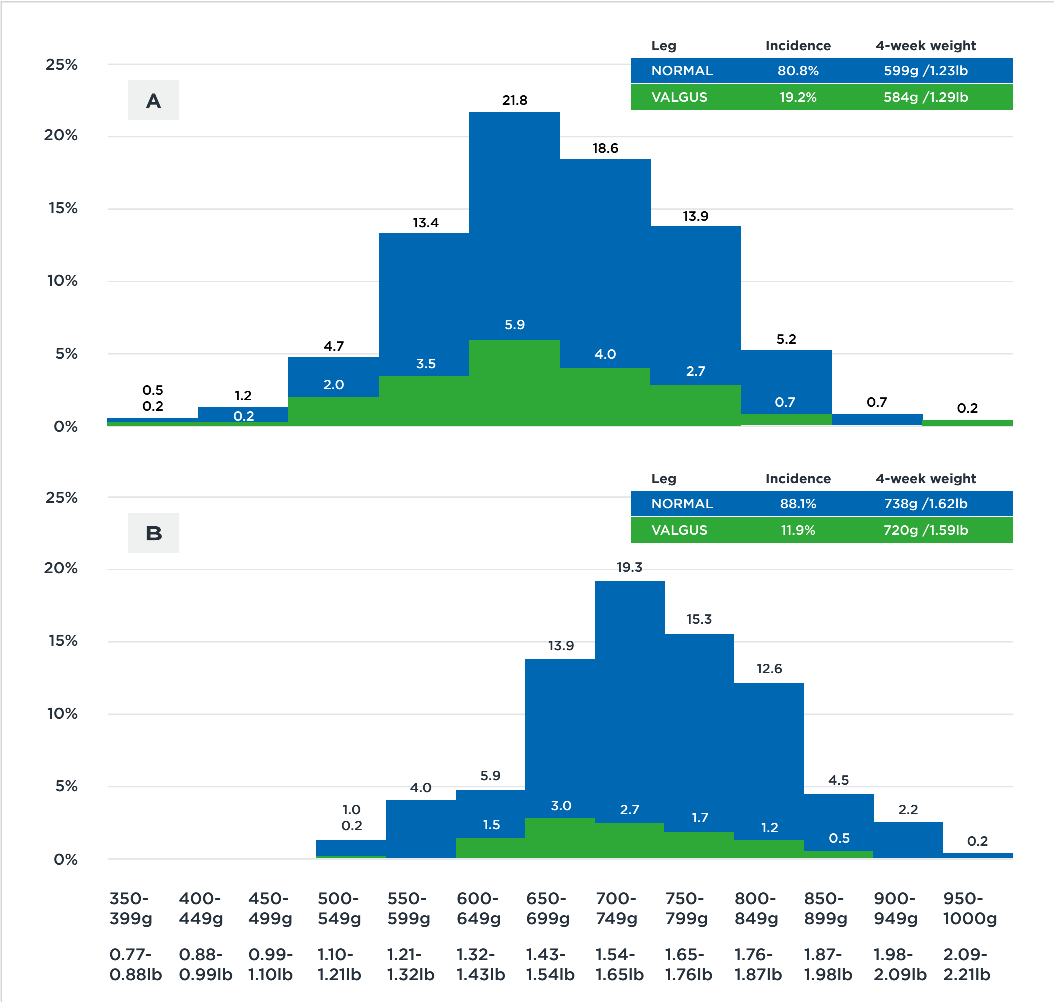



Although this trial only shows shank length data, it is possible that the heavier standard body-weight profile also impacted other parts of the body, potentially affecting the overall height of the males, allowing for better mating activity and fertility.

The benefit of rearing males according to the heavier body-weight profile was apparent in the incidence of valgus (***Figure 22***). Evaluation of valgus at 22 weeks indicated that the pre-starter diet did not influence valgus incidence. However, males reared on the Light body-weight profile (19.2%) had almost twice the incidence of valgus as the Standard profile (11.9%). The incidence of valgus in the Light profile could be attributed to the lower body-weight gain. Valgus-affected males (average body weight = 2021 g or 4.45 lb) gained 160 g or 0.35 lb (7.3%) less weight between 4 and 20 weeks of age compared to males having normal legs (average body weight = 2190 g or 4.83 lb).

It is also interesting to note that the incidence of valgus in the Light profile group was the same as in males having normal legs. This is illustrated by the same bell-shaped histogram of the 4-week body-weight distribution between the green and blue bars (***Figure 22A***). In contrast, the incidence of valgus in the profile Standard groups emerges from males having low body weight, as illustrated by the right-skewed shape of the green bars in (***Figure 22B***). This finding indicates the significance of achieving adequate body weight and flock uniformity. Moreover, the data also show that there may be benefits of achieving adequate body weight and uniformity at 4 weeks to avoid valgus incidence.

**Figure 22**
Valgus was evaluated visually at 22 weeks of age. Body-weight distribution (grams and lbs) in males at 4 weeks of age on A) Light and B) Standard. Each histogram was categorized by the incidence of valgus (Blue = Normal, Green = Valgus).




The longer shanks ***(Figure 21)*** and lower valgus incidences observed in the Standard group are positive outcomes achieved by obtaining adequate body weight and uniformity at 4 weeks while maintaining adequate body-weight gain thereafter. While this exploratory trial clearly shows the relationship between body weight, shank length, and valgus incidence, their link with fleshing is still unknown, which may also affect fertility. Future studies will consider the influence of body-weight profile and prolonged pre-starter diet on fleshing, shank length, and leg health of males during the rearing period.

# APPENDICES

**Appendix A lists the influencing factors and their level of impact on the various leg health conditions detailed in this booklet. The level of impact for each is graded by severity.**

The factors are categorized as:

**Severity 3** — a critical influence with a very high impact.

**Severity 2** — a major influence with a significant impact.

**Severity 1** — a minor influence with a lower impact.

The levels are useful for understanding the impact of each influencing factor and the extent of management practices required to prevent them. It is important to understand that the level of impact category or score for some conditions may be influenced by more than one factor, making them dependent. For example, poor enteric health can be an influencing factor for nearly all of the leg health conditions listed; however, if another factor co-exists, such as a high bacterial challenge or a dietary imbalance, one leg health condition may develop over another (such is the case with BCO, FHN & VOA and rickets, respectively).

**Appendix A**
The influencing factors of leg health and level of impact
**Severity 3** Critical;
**Severity 2** Major
**Severity 1** Minor influences.

| Leg Health Condition | Influencing Factors | Level of Impact |
|---|---|---|
| **Angular Leg Deformities, Valgus-Varus** | Body weight below standard during the first 12 weeks of life. | 3 |
| | Nutritional deficiencies | 2 |
| **Tibia Dyschondroplasia** | Ca, P, or vitamin $D_3$ deficiency, or Ca:P imbalance | 3 |
| | High Cl, high P, and low Ca, making it necessary to have an optimal dietary electrolyte balance | 2 |
| | Intestinal malabsorption | 1 |
| **Rickets** | Ca, P, or vitamin $D_3$ deficiency, or Ca:P imbalance | 3 |
| | Early rickets (vitamin $D_3$ deficiency) | 3 |
| **Long Bone Fractures** | Poor early growth and development, a prolonged period of very high egg output, and a low dietary Ca/vitamin $D_3$ | 3 |
| | Overweight birds during production | 2 |
| | Ca:P imbalance | 2 |
| **Crooked Toes** | Ca deficiency | 3 |
| | Higher than recommended stocking density in breeding stock males (3–4 males/$m^2$ or 2.7–3.6 $ft^2$/bird) | 2 |
| | Inadequate nutrient intake | 2 |
| **Ruptured Tendons** | Body weight below standard during first 12 weeks of rear | 3 |
| | Inadequate feed allocation increases (especially between 5 and 15 weeks of age) | 2 |
| | Body weight heavier than standard during production, especially after light stimulation | 2 |
| | Early reovirus infection | 3 |
| | *Staphylococcus* infection | 1 |
| | Inadequate nutrient intake in rear | 2 |
| **Male Muscle Tears** | Poor uniformity (CV% > 8% at 8 weeks) | 2 |
| | Body weight lighter than standard, especially very low body weight at 4 weeks of age | 3 |
| | Inadequate nutrient intake | 2 |
| **BCO, FHN & VOA** | High levels of bacterial challenge | 2 |
| | Injuries allowing a route of bacterial entry (including conditions that compromise the intestinal or respiratory lining (e.g., coccidiosis or infectious bronchitis) | 2 |
| | Immunosuppression or distress | 2 |
| | A combination of one or more of the preceding factors | 3 |
| | Insufficient feed allocations in rear | 1 |
| **Avian reovirus (VA, RSS & Variant ARV)** | No Maternal Antibodies (MAT) from parents followed by an early challenge on the farm | 3 |
| | A high early challenge on the farm; short downtimes implicated | 2 |
| **Infectious Synovitis** | Birds challenged with pathogenic MS strains | 1 |

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