December 2013

THE HUMANE SOCIETY OF THE UNITED STATES

An HSUS Report: The Welfare of Animals in the Chicken Industry

Abstract

More than 8.5 billion chickens are slaughtered for meat production in the United States every year. Raised in industrial production systems, these animals experience crowded indoor confinement, unnatural lighting regimes, poor air quality, stressful handling and transportation, and inadequate stunning and slaughter procedures. Because they are selectively bred for rapid growth, broiler chickens are prone to a variety of severe skeletal and metabolic disorders that can cause suffering, pain, and even death. Broiler breeders, the parent birds of chickens raised for meat, are subjected to severe feed restriction, and males may undergo painful toe and beak amputations, performed without pain relief. Scientific research on the behavior and welfare of broiler chickens demonstrates that these are substantial and important issues. Rapid and immediate reform is needed to improve the welfare of chickens raised for meat.

Introduction

Chickens raised for meat are the most numerous of any land animal farmed in the world. In a single year in the United States, more than 8.5 billion chickens, termed "broilers" by industry, are slaughtered for human consumption.[1] Over the last several decades, the broiler chicken industry has adopted the industrial model of farm animal production. As explained by the U.S. Department of Agriculture's National Agricultural Statistics Service, "The broiler industry has evolved from millions of small backyard flocks, where meat was a by-product of egg production, to less than 50 highly specialized, vertically integrated agribusiness firms."[2] Chickens are raised largely by contract producers,[3,4] who typically confine them indoors in large, warehouse-like "grow-out" facilities. These buildings, each typically 122-152 m (400-499 ft) by 12-14 m (40-46 ft),[5,6] approximate the size of a football field and might hold about 20,000 birds at one time.[7] Most operations consist of 1-4 houses, but larger broiler producers can have as many as 18 buildings.[8] Grow-out houses are usually artificially lit, force-ventilated, and completely barren except for litter material on the floor and long rows of feeders and drinkers.

Rapid Growth*

Broiler chickens have been selectively bred for rapid growth to market weight.[9] In 1920, a chicken reached 1 kg (2.2 lb) in 16 weeks,[10] but today's broiler chicken strains may now reach 2.6 kg (5.9 lb), a size large enough for slaughter,[11] in only 6 weeks.[12] Daily growth rates have increased from 25 g (0.88 oz) to 100 g (3.52 oz) in the past 50 years—an increase of more than 300%.[13] Genetic selection is so intense that the age by which broiler chickens reach market weight and are slaughtered has decreased by as much as one day every year.[14] Ongoing selection for rapid growth is a severe welfare problem as it has resulted in poor bone health,[15] leg disorders including deformities, lameness, tibial dyschondroplasia (TD), and ruptured tendons, and has been correlated with metabolic disorders such as ascites and sudden death syndrome.[16,17,18,19,20,21] Broiler chickens selected for

* For more information, see: "An HSUS Report: Welfare Issues with Selective Breeding for Rapid Growth in Broiler Chickens and Turkeys" at www.humanesociety.org/assets/pdfs/farm/welfiss_breeding_chickens_turkeys.pdf.

faster growth also suffer from weakened immune systems, making them more susceptible to a variety of additional diseases.[22]

Due in part to genetic selection for unnaturally fast growth, muscle outpaces bone development during the early life of chickens, leading to metabolic bone disease. As a result, broiler chickens often suffer from leg deformities and lameness.[23,24,25,26,27,28] Heavier broilers (>2400 g) are more likely to be lame.[29] In some cases birds become non-ambulatory,[30] completely unable to walk. Studies consistently show that approximately 26-30% of broiler chickens by 40-42 days of age suffer from gait defects severe enough to impair walking ability,[31,32,33] although at least one U.S. study reports lower levels.[34] Additional research strongly suggests that while conformational differences account for some gait differences,[35] birds at this level of lameness are probably in pain.[36,37,38] Extrapolating these percentages to the U.S. broiler chicken flock suggests that 2.2-2.6 billion chickens may have difficulty walking and experience pain. Severe leg deformities are fatal if birds can no longer stand to reach food or water;[39,40] about 1% of broiler chickens die or are culled due to leg problems.[41,42]

Valgus–varus deformity, angular bone deformity, and twisted legs are all terms used to describe deviations from normal in growth of leg bones. In addition to genetic selection, another contributing factor may be continuous bone growth associated with lack of a daily rest period (due to nearly continuous lighting, see below), which would permit the growing bones to correct the mis-alignment. These deformities are the most common cause of lameness in broiler chickens, accounting for up to 60% of skeletal disease. Ways to prevent valgus-varus deformity include slowing early growth rate and providing a long nightly dark period.[43]

Tibial dyschondroplasia (TD), an abnormal mass of cartilage at the growth plate of a bone, usually the tibia, is also a cause of leg problems. The end of the tibia may become enlarged and weakened, and the bone may bend backward as it grows. Spontaneous bone fracture and necrosis of the cartilage can occur, and in some cases, birds go down on their hocks, no longer able to stand.[44,45] Faster growing broilers are more prone to TD than slower growing birds.[46] Sources differ broadly on the prevalence of TD in broiler chicken flocks, with percentages reaching 30-40% in extreme cases.[47] Aviagen, a leading breeding company, has worked to reduce the incidence of TD, and a 2001 report estimated that the incidence of TD would fall from approximately 8% in 1989 to a projected level of less than 2% by 2005.[48] However, studies published in 2001 and 2003 report elevated cases in common commercial chicken strains, with a mean prevalence of approximately 45-57%.[49,50] While TD may be relatively common in chickens raised for meat, it is rare or absent in other types of birds.[51]

Because bone and tendon may lack sufficient strength to support the weight of the rapidly growing bird, painful tearing of tissues can occur. This is associated with several conditions including spondylolisthesis (dislocation of the fourth thoracic vertebra, which causes pinching of the spinal cord), epiphyseitis (inflammation of the growth plates), backward bending of the leg bones made weak from dyschondroplasia, and pressure-induced micro-fractures, all of which cause pain when a heavy broiler stands and walks.[52] In spondylolisthesis, damage to the spinal cord can lead to partial paralysis. Affected birds may fall to one side or are observed sitting on their tail with their feet extended.[53] Rupture of the gastrocnemius tendon, the ligament that runs along the back of the leg is another common problem in heavy broiler chickens. If one leg is affected, the added stress may cause rupture of the tendon in the other leg. Hemorrhage can lead to discoloration on the back of the legs. A ruptured tendon is a chronic, debilitating, and painful condition.[54,55]

Rapidly growing broiler chickens show altered patterns of behavior, beginning as young as two or three days old. By 17 days of age, they spend more time lying down than slow-growing broiler strains.[56] Between 5-7 weeks of age, broiler chickens spend 76-86% of their time resting, depending on the degree to which they suffer from lameness. This unusually high level of time spent lying down is thought to be related to fast growth and heavy body weight,[57] and, in turn, leads to breast blisters, hock burn, and painful[58] foot-pad dermatitis.[59] Hock burn tends to be worse in heavier birds.[60] Because sheds are sometimes cleared of litter and accumulated excrement only after several consecutive flocks have been reared,[61,62,63] the birds often must stand and lie in their own waste and that of previous flocks.

Rapid gain and increased body weight are also implicated in metabolic disorders including sudden death syndrome (SDS) and ascites, which together can account for 50% of the mortality of highly productive broiler chicken strains.[64,65] SDS is associated with acute heart failure caused by dysrhythmias.[66] Young birds die from SDS after sudden convulsions and wing-beating, and are frequently found lying on their backs.[67] The condition has been recognized since the 1950s as more broiler chickens were grown in large numbers for commercial production.[68] Between approximately 1-4% of broiler chickens may die from this condition,[69] which has been linked to their unnaturally rapid growth rate.[70]

Ascites is a condition in which rapidly growing broiler chickens do not have the heart and lung capacity needed to distribute oxygen throughout the body,[71] and is a leading cause of mortality as the birds reach market weight.[72] Characteristic symptoms include accumulation of fluid in the abdominal cavity, an enlarged flaccid heart, the appearance of a shrunken liver, and heart failure. For commercial broiler chickens, most cases are the result of pulmonary hypertension, elevated pressure in the arteries that supply blood to the lungs. The high metabolic demand for oxygen and relatively low capacity for blood flow through the lungs of rapidly growing birds increase the workload of the heart, leaving them susceptible to mortality caused by ascites.[73,74,75,76]

Even though there is evidence that genetic selection for improved leg soundness would have minimal effects on economically important carcass traits and body weight,[77] poultry breeding companies have not yet adequately addressed broiler chicken health or overall welfare. Although there are programs to improve leg health,[78,79] growth has consistently been the top selection trait in highly productive lines since the 1950s, followed only by other economically important traits, such as breast muscle (meat) yield and feed efficiency.[80,81] However, in response to consumer demand, new strains of slower growing broiler lines have been developed,[82] but these have not yet been widely adopted.

Indeed, even though leg disorders, ascites syndrome, and many other health problems are common among chickens raised for meat, producers are economically inclined to use fast-growing birds. According to Scott Beyer, a Kansas State University poultry scientist, "Although a small percentage of birds may be predisposed to leg problems, use of highly selected fast-growing strains is recommended because savings in feed costs and time far outweigh the loss of a few birds."[83]

Overcrowding

Stocking density, the number of birds per unit of floor space, indicates the level at which the animals are crowded together in a grow-out house. In the chicken meat production industry, stocking density is usually expressed in terms of live bird weight in a given area of floor space. The National Chicken Council recommends 36.6 kg/m^2 (7.5 lbs/ft^2) for a broiler chicken weighing 2.0 to 2.5 kg (4.5 to 5.5 lb).[84] For a chicken nearing market weight (2.27 kg or 5 lb), the average industry stocking density is slightly larger than the area of a single sheet of letter-sized paper, 628-762 cm^2 (97.3-118.1 in^2) per bird.[†]

Lack of adequate space can have negative consequences on the health, behavior and physiology of broiler chickens. Respirable particle (dust) concentrations are positively correlated with the biological loading, or number and weight of the birds in the buildings,[85] and ammonia concentrations increase with the stocking density,[86] although this will vary with the effectiveness of the ventilation system. Crowding at the average industry stocking density is associated with a decrease in locomotor activity,[87] and this lower level of activity has been postulated as the cause of poor walking ability found in some stocking density research.[88] Crowding also results in thigh sores and scabs, and scratches on the back[89] from birds disturbing[90] and climbing over[91] one another. When birds lie in wet litter, ammonia produced by the decomposing organic material may irritate the skin.[92] Hock and foot-pad dermatitis, lesions on the back of the legs and feet, respectively, which may be superficial or progress into deep ulcers,[93] may develop indirectly by deteriorating litter quality,[94,95,96,97,98,99] a consequence of keeping so many birds in the limited confines of the broiler house. There is also a documented

[†] Calculated from values given in: Estevez I. 2007. Density allowances for broilers: where to set the limits? Poultry Science 86:1265-72.

decrease in growth and an increase in stress indicators (H:L ratio, bursa weight) when comparing stocking densities at the industry average to lower levels.[100] At stocking densities exceeding the industry average, litter wetness due to greater fecal content, poor ventilation, and spilled water from the automated drinking system may become more problematic.[101] Air quality continues to deteriorate as stocking density increases, and broiler chickens may experience more bruising,[102] heightened fearfulness,[103] and further stress.[104,105]

Rest is important for young, growing animals,[106] and crowding increases the frequency with which birds disturb and walk over each other, interrupting resting patterns.[107,108,109] Since broiler chickens are juvenile, growing animals, stocking density is thought to be a factor that can affect their physical development. Some researchers have speculated that interrupted resting patterns may underlie bone quality problems, including decreased tibia strength and increased bone curvature. Decreased bone quality is a concern because it could in turn lead to bone fracture during catching and transport for slaughter.[110]

Scientists studying the behavior of animals have devised methods for determining how the chickens perceive the social space around them. One study used three different methods of spatial analysis including measurements of inter-individual distances, nearest neighbor distances and Dirichlet polygon areas (a measure of the space around an individual that is closer to that individual than to any other) to better understand the way broiler chickens experience different space allowances. The researchers reasoned that broiler chickens would increase the distance to their pen mates if high densities (with close proximity to pen mates) were aversive to the birds, and that they would decrease this distance if close proximity was experienced positively. The results suggested that broilers in groups of 19 birds per $3.3m^2$ (0.5 birds/ft^2), a stocking density that is far less crowded than typical US grow-out houses, started to experience the proximity of conspecifics as aversive.[111] However, the effect of crowding on the subjective state of the birds may depend on the type of behavior the bird is expressing at a particular period in time, and chickens may choose to cluster during certain activities.

Researchers have also assessed the value of additional space to the birds themselves using motivational assessment experiments. In this behavior research, spatial preference was determined by monitoring bird movements from one enclosure with 14.7 birds/m^2 (1.4 birds/ft^2) over a barrier to another enclosure with 9.3, 12.1 or 14.7 birds/m^2 (0.9, 1.1, 1.4 birds/ft^2). This corresponded to 40, 31.5 and 23.3 kg/m^2 (8.2, 6.5, and 4.8 lb/ft^2) at 39 days of age. The experiments showed that the lower the stocking density on the other side of the barrier, the more birds crossed over to the other side. Broiler chickens preferred the lower stocking density even when they had to cross over a barrier that was high enough to deter 20-25% of birds from crossing to access feed after six hours of food deprivation. The researchers concluded that broiler chickens prefer more space than the 40 kg/m^2 (8.2 lb/ft^2) provided in their study, and that a lower stocking density is therefore important to broiler chickens.[112]

Despite the clear welfare problems associated with high stocking density, broiler chicken producers have an economic incentive to overcrowd birds. Since the total kilograms produced per unit of space will increase with stocking density, profit margins will also increase to a point, as birds are raised in increasingly crowded environments.[113] As two poultry industry specialists write, "[L]imiting the floor space gives poorer results on a bird basis, yet the question has always been and continues to be: What is the least amount of floor space necessary per bird to produce the greatest return on investment?"[114]

Although reducing stocking density is important for improving the well-being of animals, large-scale studies under commercial conditions suggest that careful control of litter quality, temperature changes, ventilation, and humidity may ameliorate some of the negative effects of increased stocking density.[115,116] The maximum permitted stocking density by law in the European Union is 33 kg/m^2 (6.8 lb/ft^2), but derogations permit up to 42 kg/m^2 (8.6 lb/ft^2) if specific air quality, temperature and humidity requirements can be met.[117] For a 2.27 kg (5 lb) chicken, this is 14.5 to 18.5 birds/m^2 (1.35 to 1.72 birds/ft^2). In the United States, no laws specify minimum space requirements for broiler chickens on conventional farms.

Artificial Lighting

Although there are a wide variety of artificial lighting regimes,[118] broiler chickens are commonly reared under nearly continuous lighting.[119,120] A lighting schedule with 23 hours of light and 1 hour of darkness per 24 hours has been used to hasten growth compared to a more natural photoperiod.[121] However, reduced nightly periods of darkness are detrimental, because they limit the opportunity for sleep and rest (which is especially important for young fowl[122]), cause abnormal eye development,[123,124] and promote feeding behavior, further enhancing growth, which can exacerbate problems with leg disorders, sudden death syndrome, higher mortality, and ascites syndrome.[125,126,127,128,129,130,131,132]

These problems have not gone unnoticed by poultry scientists, and increasing the period of darkness to slow early growth is now recommended.[133] Long, uninterrupted dark periods early in their lives may reduce growth by curbing feeding activity and subsequently reduce associated health problems of broiler chickens.[134,135,136,137,138]

In the United States, 95% of chickens are raised by producers who adhere to guidelines of the National Chicken Council,[139] an industry group that recommends 4 hours of darkness, given in increments of 1, 2, or 4 hours, per 24-hour period.[140] However, a four hour period of uninterrupted darkness has been described by scientists working at the Silsoe Research Institute as an "absolute minimum" requirement.[141] Studies show that a longer period of darkness could further improve gait score (an indicator of leg problems)[142] and reduce mortality and culls.[143,144] In the European Union, a minimum of 6 hours of darkness per 24-hour period is required by law.[145]

Although the lighting in broiler chicken sheds may be nearly continuous, the light intensity is extremely dim. A typical business office may have a light level of 23.2 footcandle (250 lux),[146] but a broiler chicken shed's light intensity is often less than 1 footcandle (10 lux). Because light intensities greater than this level stimulate activity, which can decrease growth rates, many producers gradually and increasingly dim the lighting below this intensity as the birds grow.[147] Lack of brighter lighting may result in uncomfortable, eventually painful changes in the eye morphology of chickens due to abnormal eye development.[148, 149] It can also alter patterns of behavior, resulting in less preening, foraging,[150] standing, walking,[151] and overall activity.[152] Broiler chickens kept in 1 lux lighting conditions have an increased incidence of ulcerative footpad lesions compared to those kept at higher light intensities, an effect explained by additional time spent resting in low light.[153] One study found that bruising was reduced under brighter lighting conditions (180 lux), and leg disorders were lower in one trial at six weeks of age.[154] The effects of light intensity on leg health are complex, however, because another study found more hock and footpad bruising but fewer hock erosions when broiler chickens were reared at 200 lux compared to 5 or 50 lux.[155] The lack of contrast between day and night illumination during a 24-hour cycle also alters the activity patterns of broilers, and contributes to disrupted rest periods.[156,157]

Preference testing in animal behavior experiments is a powerful tool for determining the wants and needs of animals. Using this methodology, it has been determined that broiler chickens prefer different light intensities depending on the activity being performed and the age of the birds. At 2 weeks of age, broiler chicks spend more time in bright lighting (200 lux) when they have a variety of illumination level options, but by 6 weeks of age, when broiler chickens are less active, they spend more time in dimmer light (6 lux) while sitting and resting, which takes up more of their daily time-budget as they age. For all other activities six-week-old broiler chickens still preferred brighter lighting.[158]

Air Quality

Rapid deterioration of air quality within the sheds is another common result of overcrowded confinement typical of U.S. broiler chicken production systems. As successive flocks are sometimes kept on the same litter,[159,160,161,162] as mentioned above, excrement from tens of thousands of birds accumulates on the floors. Failure to clean between batches of chickens has been linked to higher respirable particle concentrations in the air of the poultry house.[163] Bacteria break down the litter and droppings, causing the air to become polluted with dust, bacteria, fungal spores, and ammonia.

Excessive ammonia levels in the litter and air can lead to ocular abnormalities,[164] eye lesions,[165] structural damage to the lungs,[166] skin and respiratory problems (such as pulmonary congestion, swelling, and hemorrhage), and even blindness.[167,168,169,170] At exposure levels of 50 parts per million (ppm) ammonia over four weeks, broiler growth is depressed and at 75 ppm for the same time period mortality levels double.[171]

When tested in behavior experiments, broiler chickens demonstrate that they find high concentrations of ammonia aversive. They will to push through weighted doors to exit an ammoniated atmosphere of 40 ppm, and the time it takes them to exit the ammoniated chamber does not increase as the door becomes heavier, demonstrating an inelastic demand for fresh air.[172] Preference testing experiments have shown that when broiler chickens are given a choice between atmospheric environments of 4, 11, 20 or 37 ppm ammonia, they will avoid the 20 or 37 ppm chambers.[173]

U.K. standards require that broiler chicken sheds not exceed ammonia levels of 20 ppm,[174] while U.S. standards permit 25 ppm.[175] However, data published in 2006 report that ammonia levels in U.S. broiler chicken sheds may reach 80 ppm, especially in the winter months when ventilation rates slow. These results show that ammonia levels can quickly become excessive as birds grow, even when they are placed initially on new litter.[176]

Ammonia fumes also inhibit chickens' sense of smell. Wrote Christopher Wathes, Professor of Animal Welfare and head of the Centre for Animal Welfare at the Royal Veterinary College, University of London, "For a bird with an acute sense of olfaction the polluted atmosphere of a poultry house may be the olfactory equivalent of looking through dark glasses."[177]

Broiler "Breeders"

Chickens used for breeding, known as "parent stock" or simply "breeders" are typically raised on separate sites from those raised for meat. Female breeding birds lay eggs that are collected, incubated, and hatched to supply chicks to the meat production sector. Broiler breeders, like their progeny, are confined in large, warehouse-like sheds with littered floors, but the buildings in which they are housed also contain long rows of nest boxes that facilitate the collection of fertilized, hatching eggs. Typically, nest boxes are elevated above floor level. Wooden or plastic slatted areas in front of the nest boxes and below the drinkers allow manure and water to pass into a pit below.

Unlike broiler chickens, who are usually slaughtered between 6-7 weeks of age,[178] mature parent stock are kept for one or, if force-molted, two years.[179] For birds, molting is a natural process of feather loss and re-growth, and results in reproductive quiescence during which hens cease egg-laying for several months. Because the time period during which females stop laying can be lengthy, commercial hatching egg producers speed up the molting process by stressing the birds with complete feed withdrawal for 10-14 days, until they lose 25% of their body weight.[180] This process is viewed by producers as "recycling" the flock,[181] as the chickens would otherwise be slaughtered and replaced by younger birds. Although male broiler breeders are typically killed and replaced after one breeding cycle (after approximately one year), some are "recycled."[182]

One of the most problematic daily welfare issues for parent birds is routine, severe feed restriction.[183,184] If allowed to feed to satiety, broiler breeders would show health and reproductive problems[185,186,187,188] due in part to their unnaturally rapid growth rate and size. As such, parent birds are usually feed-restricted, starting when they are as young as one week old.[189] In many parts of the world, including the United States, broiler breeders may be fed on a "skip-a-day" regimen in which the animals are fed as infrequently as every other day[190,191,192]—though this practice has been outlawed in several European countries.[193] In some cases, water may also be restricted in order to reduce litter moisture.[194]

Experimental studies suggest that artificial selection for increased body weight may have altered the brain mechanism controlling satiety and appetite,[195] and evidence from behavioral studies suggests that feed

restriction interferes with learning[196] and causes stress,[197, 198] boredom, and chronic hunger.[199,200,201] Breeders receive only 25-50% of the amount of feed they would otherwise eat if given free access.[202] While free-range chickens normally devote about 50% of their daily time budget foraging, [203,204] feed-restricted breeding birds can consume their daily feed allotment in as little as 15 minutes,[205] leaving a substantial amount of their daily time budget unoccupied. Feed restriction is believed to cause undernourishment, nutritional deficiency, and abnormal behavior including increased pecking at non-feed objects, pacing, heightened aggression,[206, 207] greater water intake,[208,209] and reduced resting behavior.[210] Given that target body weights for broiler breeders have changed little in the past 30 years, but broiler body weight continues to increase, the welfare of parent birds may become more serious in the future.[211] After an extensive scientific review, the European Commission's Scientific Committee on Animal Health and Animal Welfare concluded that "current commercial food restriction of breeding birds causes poor welfare."[212]

It may be possible to improve the welfare of broiler breeding hens by offering a low-density diet. Researchers have suggested that low-density diets may promote satiety by providing more bulk and gut fill, and indeed these diets can extend feeding time[213,214] and sometimes reduce stereotypic object pecking in the first half of the rearing period.[215] However, the results of different studies have been mixed, with some showing welfare benefits, but others not, and what improvements there are may not be substantial.[216] There is also, however, a promising experimental genotype (the *dw*, or "dwarf" characteristic in female hens) that may have fewer health and behavioral problems under *ad libitum* feeding.[217,218] Potential solutions to the hunger-health dilemma are possible and could be further explored with research.

To prevent males from dominating access to the feed, male broiler breeders may be fed separately from females. Several methods of excluding males from the hens' feeders are in practice. One technique uses a metal grill with partitions spaced too close together for roosters, who have slightly larger heads than breeding hens, to access the feed. However, when the birds are young, males may be small enough to reach into the feeder. To prevent the young roosters from accessing the females' feed, their nasal septums may be pierced horizontally with a plastic stick inserted into the nares (nasal openings) of their beaks, blocking them from passing their heads through the bars of the grill. These "Noz Bonz"™[219,220] undoubtedly impair welfare.

Unlike other chicken breeds,[221,222] broiler breeding males may display uncharacteristically aggressive behavior, including aberrant sexual aggression toward females during breeding, including chasing, grabbing and pulling the comb, forced copulation, and pecking the hen while mounted.[223] There have been reports of males injuring and even killing hens.[224,225,226] Studies disagree on whether or not aggression is a consequence of frustrated feeding motivation due to feed restriction,[227,228] but at least one study suggests that the problem of female-directed aggression is somehow a consequence of genetic traits and may be associated with breeding birds for meat production.[229] Large group sizes, separate rearing of males and females (which is common in commercial practice), and stocking density could all be causative factors as well.[230]

Male broiler breeders are commonly beak-trimmed, "dubbed" (their combs are cut off), and de-toed at the hatchery,[231,232,233] all performed without anesthesia or analgesia.[234,235] Beak-trimming is the removal of one-third to one-half of the beak tip,[236,237,238] an alteration meant to prevent injurious pecking. Commonly performed with a heated blade,[239,240,241] beak-trimming causes a growth setback,[242] tissue damage and nerve injury, including open wounds and bleeding, resulting in inflammation, as well as acute and possibly chronic pain[243,244,245,246,247] when a neuroma (a tangled nerve mass) forms in the healed stump of the beak.[248,249,250] De-toeing involves cutting off the hallux (the inner-most toe on each foot) to prevent the growth of claws, which can severely scratch hens during mating. Neuromas may also form during toe amputation, however the degree to which these are painful is less certain.[251]

Catching and Crating‡

When broiler chickens have reached market weight, usually between 6-7 weeks of age,[252] they are caught and crated for transport to slaughter. In the southeastern United States, where broiler chicken production is geographically concentrated,[253] opening the doors so catching crews can work lets outside air into the barn, which may cause the overall building temperature to rise.[254] Once catching ensues, the birds are typically gathered by the legs, inverted, and carried in groups of 3-4 birds per hand to transport crates.[255] During an average shift, a single catcher will lift 5-10 tons of birds at a rate of 1,000-1,500 animals per hour.[256,257] Birds experience fear, stress,[258,259,260,261] and, due to skeletal defects associated with leg problems, likely pain during the process.[262] Any elevation in temperature associated with incoming warm air increases the probability of birds experiencing heat stress and death loss.[263] Handling can become even rougher as crews become fatigued. Based on their own experience catching chickens in field tests, one team of researchers concluded that "as fatigue sets in, one's primary motivation becomes just getting the job over with. Catching and crating the birds as quickly as possible with the minimum effort possible becomes the major focus. Careful handling becomes secondary."[264]

Indeed, birds may be injured and bruised in the process, suffering dislocated and broken bones, as well as internal hemorrhages.[265,266,267, 268] One study noted:

> Hip dislocation occurs as birds are carried in the broiler sheds and loaded into the transport crates. Normally the birds are held by one leg as a bunch of birds in each hand. If one or more birds start flapping they twist at the hip, the femur detaches, and a subcutaneous haemorrhage is produced which kills the bird….Dead birds that have a dislocated hip often have blood in the mouth, which has been coughed up from the respiratory tract. Sometimes this damage is caused by too much haste on the part of the catchers.[269]

Transportation

Once the crates are loaded onto trucks, the chickens are transported to the slaughter plant. Transport causes further stress for the birds,[270,271,272,273] as they experience noise, vibration, motion, overcrowding, feed and water deprivation, social disruption, and potential temperature extremes.[274,275,276,277]

Some chickens do not survive the trip. Birds may die en route from infectious disease, heart and circulatory disorders, and trauma experienced during catching and crating,[278] including dislocated femurs, crushed skulls, and dislocated and broken bones.[279] Bone, ligament and tendon trauma associated with profuse hemorrhaging is often fatal.[280] Disease and infection problems on the farm are thought to reduce stress resistance and the ability of the birds to withstand the stresses associated with live haul.[281]

If the birds are shipped during temperature extremes, they can die from exposure in below freezing weather,[282] or heat stress during the summer.[283] Transport trucks are not uniformly ventilated, which can lead to a high temperature core, while at the same time leaving birds in locations near air inlets, such as the lower back section of the truck, exposed to wind, rain and road grit.[284] During cold, winter conditions, the amount of heat and moisture produced by the birds' bodies in crowded transport crates can overwhelm the limited passive ventilation capacity of the trailer, leading to a situation where some birds can become too hot while others become chilled and wet, and where both hyperthermia and hypothermia are possible.[285,286]

Many studies report average dead on arrival (DOA) figures. Estimates from the larger studies range from 0.12-0.46%,[287,288,289,290,291,292,293,294,295,296,297] but variation is considerable between farms, seasons and specific journeys. If these average figures are applied to the approximate figure of 8.5 billion broiler chickens slaughtered in the United States annually, it suggests that about 10-39 million birds die during transport every year.

‡ For more information, see: "An HSUS Report: Welfare Issues with Conventional Manual Catching of Broiler Chickens and Turkeys" at www.humanesociety.org/assets/pdfs/farm/HSUS-Report-on-Manual-Catching-of-Poultry.pdf.

Handling-related conditions contributing to DOA counts[298]	
Condition	**Total DOA %**
Ruptured liver	25.0
Ruptured lung	15.0
Head trauma	13.5
Asphyxia	13.5
Leg trauma	12.0
Mutilation (multiple trauma)	5.5
Miscellaneous broken bone	3.0
Unknown	12.5

Farm-related conditions contributing to DOA counts[299]	
Condition	**Total DOA %**
Airsacculitis and septicemia	58.0
Ascites	31.0
Cull	7.0
Unknown	4.0

Factors leading to higher DOA numbers include longer transport time or distances, [300,301,302,303,304,305] temperature and season of the year, [306,307,308,309,310] increased stocking density in the transport crates and on the truck, [311,312,313] increased bird body weight,[314,315] and climatic conditions such as wind and rain.[316] Careful management of the catching, crating and transport process can reduce the effects of these factors. For example, large, portable fans can be used to blow air through loaded, stationary trailers; financial incentive programs to reduce traumatic injuries caused by catching crews can be instituted;[317] mechanical ventilation systems can be used to keep the thermal environments of poultry transport vehicles within the prescribed range, 20-21 ºC (68-70 ºF); [318] holding areas in hot and humid regions can be climate controlled;[319] and arrival times to reduce time in lairage can be carefully planned to improve the welfare of the birds.

Slaughter

At the slaughter plant, transport crates are unloaded from the trucks and the chickens are dumped onto conveyors and hung upside-down in shackles by their legs. Shackling is painful,[320,321] and this pain is likely to be worse in birds suffering from diseases or abnormalities of leg joints or leg bones,[322,323] especially those with dislocated joints or bone fractures induced by rough handling during catching, crating, and uncrating,[324] and for large broiler breeders if their shanks are too big for the shackles.[325] Moreover, hanging upside-down is a physiologically abnormal posture for chickens. Handling, inversion, and shackling are traumatic and stressful, as reported in multiple studies that measured physiological indicators of stress.[326,327,328,329] Birds may struggle in the shackles[330] and commonly flap their wings vigorously,[331] which may lead to additional dislocated joints and broken bones.[332]

Despite the fact that birds make up more than 95% of all land animals slaughtered for food in the United States,[§] the U.S. Department of Agriculture (USDA) does not include them under the protections of the Humane

[§] Calculated from values given in: U.S. Department of Agriculture National Agricultural Statistics Service. 2013. Livestock slaughter: 2012 summary; and U.S. Department of Agriculture National Agricultural Statistics Service. 2012. Poultry slaughter: 2013 annual summary.

Methods of Slaughter Act.[333] Thus, there is no legal requirement that chickens must be rendered unconscious before they are slaughtered. However most chickens are conveyed through an electrified water bath, which is meant to stun and immobilize them before they are killed by an automated knife. Following throat-cutting, the birds die from exsanguination (blood loss). After the bleed-out process, birds enter the scald tank in preparation for the next step, mechanical feather plucking. Line speeds may be as fast as 140-180 birds per minute.[334]

It is well-documented in the scientific and trade literature that some birds experience painful electric shocks prior to being conveyed through the electrified water bath.[335,336,337,338,339,340] This can happen when a bird's leading wing makes contact with the water before the head does or if wing-flapping occurs at the entrance to the stunner.[341] Newer designs in stunners may, however, prevent overflow of electrically charged brine onto the entry ramp,[342] and can lower the incidence of pre-stun electrical shocks.[343]

Scientific studies suggest that the electrical stunning process itself may not be instantaneous or effective. Although it is theoretically possible to induce immediate unconsciousness using electricity of sufficient magnitude, evidence that this occurs in commercial practice in the United States is lacking. The World Animal Health Organization, of which the United States is a member country, has specified internationally recognized parameters for the stunning and killing of poultry at slaughter in the *Terrestrial Animal Health Code* (TAHC),[344] to ensure the welfare of the birds. Section 7.5.7.3.b of the TAHC specifies that the amount of current necessary to stun chickens when using a frequency of 200-400 Hz is 150 milliamperes (mA) per bird, and when using a frequency of 400-1500 Hz, 200 mA is necessary.[345] However, in the United States, while the use of 350-500 Hz frequency settings is common, electrical water-bath stunners may be set at only 10-28 volts, delivering 10-45 mA per bird. [346,347,348] This low voltage/current setting is not utilized in Europe,[349] and is based on meat quality concerns.[350] Research published in 2006 suggests that the electrical settings currently in use in U.S. slaughter plants probably do not render all birds immediately unconscious.[351,352]

Of further concern is that some birds are conveyed through the stunner without ever making contact with the electrified water bath. This can happen if birds struggle and lift their heads, the height of the stunner is not correctly adjusted, or birds are too short to reach the water-bath.[353,354,355] In 2007, one of the top disease challenges facing poultry veterinarians in the United States was Runting Stunting Syndrome (RSS). RSS-affected flocks have poor uniformity, hindering processability,[356] possibly worsening the problem of small birds missing the stunner.

Occasionally, live birds who were not adequately stunned and/or who missed the killing machine, or recovered from the stun due to poor neck-cutting practices are conscious when entering the scald tank.[357,358,359,360] Although a worker is present on the slaughter line to manually cut the throats of birds who miss the automated blade, in high-throughput processing plants, rapid line speeds can prevent the detection of live birds exiting the killing machine.[361] In U.S. plants with improper supervision, the rate at which birds enter the scald tank while still alive may be as high as 3%.[362] According to the USDA's Food Safety and Inspection Service "Poultry Slaughter Inspection Training" guide, "Poultry that die from causes other than slaughter are condemned under the cadaver category. These birds are not dead when they enter the scald vat. When submerged in the hot water, they drown…."[363] In 2012, 729,189 chickens were condemned under this category.[364]

More effective and less aversive alternatives to electrified water-bath stunning slaughter are Controlled Atmosphere Stunning (CAS) and Controlled Atmosphere Killing (CAK) systems. In these systems, animals are not handled while they are still conscious, avoiding the problems associated with dumping,[**] handling, and shackling live birds, and the systems do not risk pre-stun shocks and/or ineffective stunning. In CAS and CAK systems, birds are conveyed through a tunnel filled with carbon dioxide (CO_2), inert gases (argon or nitrogen), or a mixture of these gases. With CAK, birds are exposed to lethal concentrations of gases long enough that they

[**] Some gas systems are designed in such a way that birds must still be dumped from their transport crates prior to entering the gas-filled chamber on a conveyer belt. While still retaining many of the welfare advantages of CAS and CAK systems, those that move birds through the gaseous atmosphere while they are still in their transport crates are considered optimal.

are actually killed, rather than simply stunned,[365] whereas with CAS, the gas or gases induce unconsciousness as the birds pass through before they are hung on shackles, while insensible, and conveyed to the killing machine for slaughter. In both systems, hanging operators do not shackle the birds until after they exit the gas stunning system, so the animals do not endure the pain, fear, and stress associated with this step in the procedure, and there is no potential for pre-stun electric shock or birds missing the stunner.

Conclusion

Many standard practices in the broiler chicken industry are in dire need of reform, as they are simply inhumane. At every stage of the process—from breeding all the way to slaughter— there are substantial welfare issues. Practices must be reevaluated in light of bird welfare concerns in an effort to reduce suffering and enhance quality of life. There are many potential innovations in genetics, [366] lighting programs, [367] environmental enrichment,[368,369] and technology for catching,[370,371] transporting,[372] and slaughtering chickens that could greatly improve the welfare of these animals if more widely adopted within the industry.

While all welfare problems of broiler chickens are important, selective breeding for growth without due attention to animal health and well-being, which has resulted in animals who are chronically in pain, is wholly unacceptable. Broiler chickens grow so quickly that they are "on the verge of structural collapse."[373] According to John Webster, Emeritus Professor of Animal Husbandry at the University of Bristol, "[T]his must constitute, in both magnitude and severity, the single most severe, systematic example of man's inhumanity to another sentient animal."[374] There are only three major breeding companies that offer commercial broiler lines: Hubbard, Cobb-Vantress (Cobb strains), and Aviagen (Ross strains). Each of these companies now offers a line of slower growing birds. Wider use of these lines could markedly improve the welfare of chickens raised for meat production.[375]

Chickens are living, sentient individuals and must be recognized as such, rather than commodified and viewed simply as "products"[376,377] or "breeders." Scientists are increasingly recognizing the complex cognitive abilities of birds,[378,379] their capacity to suffer,[380] and the ethical implications that these findings carry. Billions of birds in the United States and globally will continue to suffer in industrial production if scientifically documented welfare problems continue to be minimized and left unaddressed by the meat industry.

---

[1] U.S. Department of Agriculture National Agricultural Statistics Service. 2013. Poultry slaughter: 2012 summary. http://usda01.library.cornell.edu/usda/current/PoulSlauSu/PoulSlauSu-02-25-2013.pdf. Accessed December 3, 2013.
[2] U.S. Department of Agriculture National Agricultural Statistics Service. 2002. U.S. broiler industry structure. Agricultural Statistics Board. http://usda01.library.cornell.edu/usda/nass/industry-structure/specpo02.pdf. Accessed December 3, 2013.
[3] Perry J, Banker D, and Green R. 1999. Broiler Farms' Organization, Management, and Performance. Resource Economics Division, Economic Research Service, U.S. Department of Agriculture. Agriculture Information Bulletin No. 748. www.ers.usda.gov/publications/aib-agricultural-information-bulletin/aib748.aspx. Accessed December 3, 2013.
[4] MacDonald JM. 2008. The Economic Organization of U.S. Broiler Production. U.S. Department of Agriculture, Economic Information Bulletin Number 38. www.ers.usda.gov/media/205671/eib38_1_.pdf. Accessed December 3, 2013.
[5] Watt Poultry USA. 2005. Housing expansion plans. Watt Poultry USA, June, pp. 24-8.
[6] Etter L. 2009. Farmers face empty-nest syndrome amid chicken housing crisis. The Wall Street Journal, February 12. http://online.wsj.com/article/SB123440092979675383.html. Accessed December 3, 2013.
[7] Etter L. 2009. Farmers face empty-nest syndrome amid chicken housing crisis. The Wall Street Journal, February 12. http://online.wsj.com/article/SB123440092979675383.html. Accessed December 3, 2013.
[8] MacDonald JM. 2008. The Economic Organization of U.S. Broiler Production. U.S. Department of Agriculture, Economic Information Bulletin Number 38. www.ers.usda.gov/media/205671/eib38_1_.pdf. Accessed December 3, 2013.

[9] Boersma S. 2001. Managing rapid growth rate in broilers. World Poultry 17(8):20-1.
[10] Aho PW. 2002. Introduction to the US chicken meat industry. In: Bell DD and Weaver WD Jr (eds.), Commercial Chicken Meat and Egg Production, 5th Edition (Norwell, MA: Kluwer Academic Publishers).
[11] U.S. Department of Agriculture National Agricultural Statistics Service. 2013. Poultry slaughter: 2012 summary. http://usda01.library.cornell.edu/usda/current/PoulSlauSu/PoulSlauSu-02-25-2013.pdf. Accessed December 3, 2013.
[12] Aviagen. 2012. Ross 708 Broiler Performance Objectives, p. 9. http://en.aviagen.com/assets/Tech_Center/Ross_Broiler/Ross708BroilerPerfObj2012R1.pdf. Accessed December 3, 2013.
[13] Knowles TG, Kestin SC, Haslam SM, et al. 2008. Leg disorders in broiler chickens: prevalence, risk factors and prevention. PLoS ONE 3(2):e1545. doi:10.1371/journal.pone.0001545. www.plosone.org/article/info:doi/10.1371/journal.pone.0001545. Accessed December 3, 2013.
[14] Weeks C. 2004. Introduction. In: Weeks C and Butterworth A (eds.), Measuring and Auditing Broiler Welfare (Wallingford, U.K.: CABI Publishing, p. xiii).
[15] Shim MY, Karnuah AB, Mitchell AD, Anthony NB, Pesti GM, and Aggrey SE. 2012. The effects of growth rate on leg morphology and tibia breaking strength, mineral density, mineral content, and bone ash in broilers. Poultry Science 91:1790-5.
[16] Boersma S. 2001. Managing rapid growth rate in broilers. World Poultry 17(8):20-1.
[17] Julian RJ. 2004. Evaluating the impact of metabolic disorders on the welfare of broilers. In: Weeks C and Butterworth A (eds.), Measuring and Auditing Broiler Welfare (Wallingford, U.K.: CABI Publishing).
[18] Bessei W. 2006. Welfare of broilers: a review. World's Poultry Science Journal 62:455-66.
[19] EFSA Panel on Animal Health and Welfare. 2010. Scientific Opinion on the influence of genetic parameters on the welfare and the resistance to stress of commercial broilers. EFSA Journal 8(7):1666. www.efsa.europa.eu/en/efsajournal/doc/1666.pdf. Accessed December 3, 2013.
[20] Kestin SC, Gordon S, Su G, and Sørensen P. 2001. Relationships in broiler chickens between lameness, liveweight, growth rate and age. Veterinary Record. 148:195-7.
[21] Bradshaw RH, Kirkden RD, and Broom DM. 2002. A review of the aetiology and pathology of leg weakness in broilers in relation to welfare. Avian and Poultry Biology Reviews 13(2):45-103.
[22] Rauw WM, Kanis E, Noordhuizen-Stassen EN, and Grommers FJ. 1998. Undesirable side effects of selection for high production efficiency in farm animals: a review. Livestock Production Science 56:15-33.
[23] Leeson S, Diaz G, and Summers JD. 1995. Poultry Metabolic Disorders and Mycotoxins (Guelph, Canada: University Books, p. 140).
[24] Mench JA. 2004. Lameness. In: Weeks C and Butterworth A (eds.), Measuring and Auditing Broiler Welfare (Wallingford, U.K.: CABI Publishing).
[25] Bessei W. 2006. Welfare of broilers: a review. World's Poultry Science Journal 62:455-66.
[26] Sanotra GS, Lund JD, Ersbøll AK, Petersen JS, and Vestergaard KS. 2001. Monitoring leg problems in broilers: a survey of commercial broiler production in Denmark. World's Poultry Science Journal 57:55-69.
[27] Scientific Committee on Animal Health and Animal Welfare. 2000. The welfare of chickens kept for meat production (broilers). For the European Commission. http://ec.europa.eu/food/fs/sc/scah/out39_en.pdf. Accessed December 3, 2013.
[28] Julian RJ. 2005. Production and growth related disorders and other metabolic diseases of poultry – A review. The Veterinary Journal 169:350-69.
[29] Kristensen H.H., Perry GC, Prescott NB, Ladewig J, Ersbøll AK, and Wathes CM. 2006. Leg health and performance of broiler chickens reared in different light environments. British Poultry Science 47(3): 257-63.
[30] Julian RJ. 1998. Rapid growth problems: ascites and skeletal deformities in broilers. Poultry Science 77:1773-80.
[31] Knowles TG, Kestin SC, Haslam SM, et al. 2008. Leg disorders in broiler chickens: prevalence, risk factors and prevention. PLoS ONE 3(2):e1545. doi:10.1371/journal.pone.0001545. www.plosone.org/article/info:doi/10.1371/journal.pone.0001545. Accessed December 3, 2013.
[32] Kestin SC, Knowles TG, Tinch AE, and Gregory NG. 1992. Prevalence of leg weakness in broiler chickens and its relationship with genotype. The Veterinary Record 131:190-4.

[33] Sanotra GS, Berg C, and Lund JD. 2003. A Comparison Between Leg Problems in Danish and Swedish Broiler Production. Animal Welfare 12:677-83.
[34] Oviedo-Rondón EO, Wineland MJ, Funderburk S, Small J, Cutchin H, and Mann M. 2009. Incubation conditions affect leg health in large, high-yield broilers. Journal of Applied Poultry Research 18:640–6.
[35] Skinner-Noble DO and Teeter RG. 2009. An examination of anatomic, physiologic, and metabolic factors associated with well-being of broilers differing in field gait score. Poultry Science 88:2-9.
[36] Danbury TC, Weeks CA, Chambers JP, Waterman-Pearson AE, and Kestin SC. 2000. Self-selection of the analgesic drug carprofen by lame broiler chickens. The Veterinary Record 146:307-11.
[37] McGeown D, Danbury TC, Waterman-Pearson AE, and Kestin SC. 1999. Effect of carprofen on lameness in broiler chickens. The Veterinary Record 144:668-71.
[38] Nääs IA, Paz ICLA, Baracho MS, et al., 2009. Impact of lameness on broiler well-being. Journal of Applied Poultry Research 18:432-9.
[39] Sørensen P, Su G, and Kestin SC. 1999. The effect of photoperiod: scotoperiod on leg weakness in broiler chickens. Poultry Science 78:336-42.
[40] Dinev I. 2009. Clinical and morphological investigations on the prevalence of lameness associated with femoral head necrosis in broilers. British Poultry Science 50(3):284-90.
[41] Riddell C and Springer R. 1985. An epizootiological study of acute death syndrome and leg weakness in broiler chickens in Western Canada. Avian Diseases 29:90-102.
[42] Morris MP. 1993. National survey of leg problems. Broiler Industry, May, pp. 20-4.
[43] Julian RJ. 2005. Production and growth related disorders and other metabolic diseases of poultry – A review. The Veterinary Journal 169:350-69.
[44] Julian RJ. 2004. Evaluating the impact of metabolic disorders on the welfare of broilers. In: Weeks C and Butterworth A (eds.), Measuring and Auditing Broiler Welfare (Wallingford, U.K.: CABI Publishing).
[45] Julian RJ. 2005. Production and growth related disorders and other metabolic diseases of poultry – A review. The Veterinary Journal 169:350-69.
[46] Shim MY, Karnuah AB, Anthony NB, Pesti GM, and Aggrey SE. 2012. The effects of broiler chicken growth rate on valgus, varus, and tibial dyschondroplasia. Poultry Science 91:62-5.
[47] Leeson S, Diaz GJ, and Summers JD. 1995. Poultry Metabolic Disorders and Mycotoxins (Guelph, Canada: University Books, p. 140).
[48] Aviagen. 2001. Ross Tech 01/40. Leg health in broilers. www.thepoultrysite.com/downloads/single/116/. Accessed December 3, 2013.
[49] Sanotra GS, Lund JD, Ersbøll AK, Petersen JS, and Vestergaard KS. 2001. Monitoring leg problems in broilers: a survey of commercial broiler production in Denmark. World's Poultry Science Journal 57:55-69.
[50] Sanotra GS, Berg C, and Lund JD. 2003. A comparison between leg problems in Danish and Swedish broiler production. Animal Welfare 12:677-83.
[51] Julian RJ. 1998. Rapid growth problems: ascites and skeletal deformities in broilers. Poultry Science 77:1773-80.
[52] Julian RJ. 2005. Production and growth related disorders and other metabolic diseases of poultry – A review. The Veterinary Journal 169:350-69.
[53] Julian RJ. 2005. Production and growth related disorders and other metabolic diseases of poultry – A review. The Veterinary Journal 169:350-69.
[54] Julian RJ. 2004. Evaluating the impact of metabolic disorders on the welfare of broilers. In: Weeks C and Butterworth A (eds.), Measuring and Auditing Broiler Welfare (Wallingford, U.K.: CABI Publishing).
[55] Julian RJ. 2005. Production and growth related disorders and other metabolic diseases of poultry – A review. The Veterinary Journal 169:350-69.
[56] Bizeray D, Leterrier C, Constantin, P, Picard M and Faure JM. 2000. Early locomotor behaviour in genetic stocks of chickens with different growth rates. Applied Animal Behaviour Science 68:231-42.
[57] Weeks CA, Danbury TD, Davies HC, Hunt P, and Kestin SC. 2000. The behaviour of broiler chickens and its modification by lameness. Applied Animal Behaviour Science 67:111-25.
[58] Gentle MJ. 2011. Pain issues in poultry. Applied Animal Behaviour Science 135:252-8.
[59] Estevez I. 2002. Poultry welfare issues. Poultry Digest Online 3(2):1-12. http://ansc.umd.edu/extension/poultry/documents/Poultry_Welfare_Behavior/publications/Poultry%20Welfare%

20Issues,%20Poultry%20Digest%20Onine%20Volume%203%20Number%202.pdf. Accessed December 3, 2013.
[60] Kristensen H.H., Perry GC, Prescott NB, Ladewig J, Ersbøll AK, and Wathes CM. 2006. Leg health and performance of broiler chickens reared in different light environments. British Poultry Science 47(3): 257-63.
[61] Dozier WA III, Lacy MP, and Vest LR. 2001. Broiler production and management. The University of Georgia College of Agricultural and Environmental Sciences, Cooperative Extension Service..
[62] Carlile FS. 1984. Ammonia in poultry houses: a literature review. World's Poultry Science Journal 40:99-113.
[63] Lacy MP. 2002. Broiler management. In: Bell DD and Weaver WD Jr (eds.), Commercial Chicken Meat and Egg Production, 5th Edition (Norwell, MA: Kluwer Academic Publishers).
[64] Gardiner EE, Hunt JR, Newberry RC, and Hall JW. 1988. Relationships between age, body weight, and season of the year and the incidence of sudden death syndrome in male broiler chickens. Poultry Science 67:1243-9.
[65] Gonzales E, Buyse J, Takita TS, Sartori JR and Decuypere E, 1998. Metabolic disturbances in male broilers of different strains. 1. Performance, mortality, and right ventricular hypertrophy. Poultry Science 77:1646–53.
[66] Riddell C and Springer R. 1985. An epizootiological study of acute death syndrome and leg weakness in broiler chickens in Western Canada. Avian Diseases 29:90-102.
[67] Julian RJ. 2004. Evaluating the impact of metabolic disorders on the welfare of broilers. In: Weeks C and Butterworth A (eds.), Measuring and Auditing Broiler Welfare (Wallingford, U.K.: CABI Publishing).
[68] Julian RJ. 2005. Production and growth related disorders and other metabolic diseases of poultry – A review. The Veterinary Journal 169:350-69.
[69] Olkowski AA and Classen HL. 1997. Malignant ventricular dysrhythmia in broiler chickens dying of sudden death syndrome. The Veterinary Record 140:177-9.
[70] Riddell C and Springer R. 1985. An epizootiological study of acute death syndrome and leg weakness in broiler chickens in Western Canada. Avian Diseases 29:90-102.
[71] Duncan IJH. 2001. Animal welfare issues in the poultry industry: is there a lesson to be learned? Journal of Applied Animal Welfare Science 4(3):207-21.
[72] Boersma S. 2001. Managing rapid growth rate in broilers. World Poultry 17(8):20-1.
[73] Balog JM. 2003. Ascites syndrome (pulmonary hypertension syndrome) in broiler chickens: are we seeing the light at the end of the tunnel? Avian and Poultry Biology Reviews 14(3):99-126.
[74] Julian RJ. 2000. Physiological, management and environmental triggers of the ascites syndrome: a review. Avian Pathology 29(6):519-27.
[75] Boersma S. 2001. Managing rapid growth rate in broilers. World Poultry 17(8):20-1.
[76] Julian RJ. 2005. Production and growth related disorders and other metabolic diseases of poultry – A review. The Veterinary Journal 169:350-69.
[77] Rekaya R, Sapp RL, Wing T, and Aggrey SE. 2013. Genetic evaluation for growth, body composition, feed efficiency, and leg soundness. Poultry Science 92:923-9.
[78] Kapell DNRG, Hill WG, Neeteson AM, McAdam J, Koerhuis ANM, and Avendaño S. 2012. Twenty-five years of selection for improved leg health in purebred broiler lines and underlying genetic parameters. Poultry Science 91:3032-43.
[79] Katanbaf MN and Hardiman JW. 2010. Primary broiler breeding—Striking a balance between economic and well-being traits. Poultry Science 89:822-4.
[80] Rauw WM, Kanis E, Noordhuizen-Stassen EN, and Grommers FJ. 1998. Undesirable side effects of selection for high production efficiency in farm animals: a review. Livestock Production Science 56(1):15-33.
[81] Arthur JA and Albers GAA. 2003. Industrial perspective on problems and issues associated with poultry breeding. In: Muir WM and Aggrey SE (eds.), Poultry Genetics, Breeding and Biotechnology (Wallingford, U.K.: CAB International).
[82] Cooper MD and Wrathall JHM. 2010. Assurance schemes as a tool to tackle genetic welfare problems in farm animals: broilers. Animal Welfare 19(Supplement):51-6.
[83] Beyer RS. 2002. Leg problems in broilers and turkeys. Kansas State University Agricultural Experiment Station and Cooperative Extension Service, June.
www.ksre.ksu.edu/bookstore/Item.aspx?catId=578&pubId=216. Accessed December 3, 2013.

[84] National Chicken Council. 2010. National Chicken Council Animal Welfare Guidelines and Audit Checklist for Broilers. www.nationalchickencouncil.org/wp-content/uploads/2012/01/NCC-Animal-Welfare-Guidelines-2010-Revision-BROILERS.pdf. Accessed December 3, 2013.
[85] Banhazi TM, Seedorf J, Laffrique M, and Rutley DL. 2008. Identification of the risk factors for high airborne particle concentrations in broiler buildings using statistical modelling. Biosystems Engineering 101(1):100-10.
[86] AL Homidan A and Robertson JF. 2003. Effect of litter type and stocking density on ammonia, dust concentrations and broiler performance. British Poultry Science 44 S7-8.
[87] Simitzis, PE, Kalogeraki E, Goliomytis M, et al. 2012 Impact of stocking density on broiler growth performance, meat characteristics, behavioural components and indicators of physiological and oxidative stress. British Poultry Science 53(6):721-30.
[88] Sørensen P, Su G, and Kestin SC. 2000. Effects of age and stocking density on leg weakness in broiler chickens. Poultry Science 79(6):864-70.
[89] Bilgili SF and Hess JB. 1995. Placement density influences broiler carcass grade and meat yields. Journal of Applied Poultry Research 4:384-9.
[90] Estevez I. 2007. Density allowances for broilers: where to set the limits? Poultry Science 86:1265-72.
[91] Hargis BM, Moore RW, and Sams AR. 1989. Toe scratches cause scabby hip syndrome lesions. Poultry Science 68:1148-9.
[92] Estevez I. 2002. Poultry welfare issues. Poultry Digest Online 3(2):1-12. http://ansc.umd.edu/extension/poultry/documents/Poultry_Welfare_Behavior/publications/Poultry%20Welfare%20Issues,%20Poultry%20Digest%20Onine%20Volume%203%20Number%202.pdf. Accessed December 3, 2013.
[93] McMullin P. 2004. A Pocket Guide to Poultry Health and Disease, First Edition (Sheffield, U.K.: 5M Enterprises Limited, pp.111-2).
[94] Arnould C and Faure JM. 2003. Use of pen space and activity of broiler chickens reared at two different densities. Applied Animal Behaviour Science 84(4):281-96.
[95] Dozier WA III, Thaxton JP, Branton SL, et al. 2005. Stocking density effects on growth performance and processing yields of heavy broilers. Poultry Science 84:1332-8.
[96] Ventura BA, Siewerdt F, and Estevez I. 2010. Effects of barrier perches and density on broiler leg health, fear, and performance. Poultry Science 89:1574-83.
[97] Simsek UG, Dalkilic B, Ciftci M, and Yuce A. 2009. The influences of different stocking densities on some welfare indicators, lipid peroxidation (MDA), and antioxidant enzyme activities (GSH, GSH-Px, CAT) in broiler chickens. Journal of Animal and Veterinary Advances 8(8):1568-72.
[98] Meluzzi A, Fabbri C, Folegatti E, and Sirri F. 2008. Effect of less intensive rearing conditions on litter characteristics, growth performance, carcase injuries and meat quality of broilers. British Poultry Science 49(5):509-15.
[99] Shepherd EM and Fairchild BD. 2010. Footpad dermatitis in poultry. Poultry Science 89(10):2043-51.
[100] Simitzis, PE, Kalogeraki E, Goliomytis M, et al. 2012 Impact of stocking density on broiler growth performance, meat characteristics, behavioural components and indicators of physiological and oxidative stress. British Poultry Science 53(6):721-30.
[101] Estevez I. 2002. Poultry welfare issues. Poultry Digest Online 3(2):1-12. http://ansc.umd.edu/extension/poultry/documents/Poultry_Welfare_Behavior/publications/Poultry%20Welfare%20Issues,%20Poultry%20Digest%20Onine%20Volume%203%20Number%202.pdf. Accessed December 3, 2013.
[102] Hall AL. 2001. The effect of stocking density on the welfare and behaviour of broiler chickens reared commercially. Animal Welfare 10:23-40.
[103] Sanotra GS, Lawson LG, Vestergaard KS, and Thomsen MG. 2001. Influence of stocking density on tonic immobility, lameness, and tibial dyschondroplasia in broilers. Journal of Applied Animal Welfare Science 4(1):71-87.
[104] Villagrá A, Ruiz de la Torre JL, Chacón G, Lainez M, Torres A, and Manteca X. 2009. Stocking density and stress induction affect production and stress parameters in broiler chickens. Animal Welfare 18:189-97.

[105] Simsek UG, Dalkilic B, Ciftci M, and Yuce A. 2009. The influences of different stocking densities on some welfare indicators, lipid peroxidation (MDA), and antioxidant enzyme activities (GSH, GSH-Px, CAT) in broiler chickens. Journal of Animal and Veterinary Advances 8(8):1568-72.
[106] Duncan IJH. 2004. Welfare problems of poultry. In: Benson GJ and Rollin BE (eds.), The Well-Being of Farm Animals: Challenges and Solutions (Ames, IA: Blackwell Publishing).
[107] Hall AL. 2001. The effect of stocking density on the welfare and behaviour of broiler chickens reared commercially. Animal Welfare 10:23-40.
[108] Febrer K, Jones TA, Donnelly CA, and Dawkins MS. 2006. Forced to crowd or choosing to cluster? Spatial distribution indicates social attraction in broiler chickens. Animal Behaviour 72(6):1291-300.
[109] Buijs S, Keeling LJ, Vangestel C, Baert J, Vangeyte J, and Tuyttens FAM. 2010. Resting or hiding? Why broiler chickens stay near walls and how density affects this. Applied Animal Behaviour Science 124 (3-4):97–103.
[110] Buijs S, Van Poucke E, Van Dongen S, Lens L, Baert J, Tuyttens FAM. 2012. The influence of stocking density on broiler chicken bone quality and fluctuating asymmetry. Poultry Science 91: 1759-67.
[111] Buijs S, Keeling LJ, Vangestel C, Baert J, and Tuyttens FAM. 2011. Neighbourhood analysis as an indicator of spatial requirements of broiler chickens. Applied Animal Behaviour Science 129(2/4):111-20.
[112] Buijs S, Keeling LJ, Tuyttens FAM. 2011. Using motivation to feed as a way to assess the importance of space for broiler chickens. Animal Behaviour 81:145-51.
[113] Puron D, Santamaria R, Segura JC, and Alamilla JL. 1995. Broiler performance at different stocking densities. Journal of Applied Poultry Research 4:55-60.
[114] North MO and Bell DD. 1990. Commercial Chicken Production Manual, 4th Edition (New York, NY: Van Nostrand Reinhold, p. 456).
[115] Jones TA, Donnelly CA, and Dawkins MS. 2005. Environmental and management factors affecting the welfare of chickens on commercial farms in the United Kingdom and Denmark stocked at five densities. Poultry Science 84:1155-65.
[116] Dawkins MS, Donnelly CA, and Jones TA. 2004. Chicken welfare is influenced more by housing conditions than by stocking density. Nature 427:342-4.
[117] Council Directive 2007/43/EC of 28 June 2007 laying down minimum rules for the protection of chickens kept for meat production. Official Journal of the European Union L 182/19. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:182:0019:0028:EN:PDF. Accessed December 3, 2013.
[118] Knowles TG, Kestin SC, Haslam SM, et al. 2008. Leg disorders in broiler chickens: prevalence, risk factors and prevention. PLoS ONE 3(2):e1545. doi:10.1371/journal.pone.0001545. www.plosone.org/article/info:doi/10.1371/journal.pone.0001545. Accessed December 3, 2013.
[119] Hester PY. 1994. The role of environment and management on leg abnormalities in meat-type fowl. Poultry Science 73:904-15.
[120] Duncan IJH. 2004. Welfare problems of poultry. In: Benson GJ and Rollin BE (eds.), The Well-Being of Farm Animals: Challenges and Solutions (Ames, IA: Blackwell Publishing).
[121] Lacy MP. 2002. Broiler management. In: Bell DD and Weaver WD Jr (eds.), Commercial Chicken Meat and Egg Production, 5th Edition (Norwell, MA: Kluwer Academic Publishers).
[122] Malleau AE, Duncan IJH, Widowski TM, and Atkinson JL. 2007. The importance of rest in young domestic fowl. Applied Animal Behaviour Science 106:52-69.
[123] Lewis PD and Gous RM. 2009. Photoperiodic responses of broilers. II. Ocular development. British Poultry Science 50(6):667-72.
[124] Schwean-Lardner K, Fancher BI, Gomis S, Van Kessel A, Dalal S, and Classen HL. 2013. Effect of day length on cause of mortality, leg health, and ocular health in broilers. Poultry Science 92:1-11.
[125] Prescott NB, Kristensen HH, and Wathes CM. 2004. Light. In: Weeks CA and Butterworth A (eds.), Measuring and Auditing Broiler Welfare (Wallingford, U.K.: CAB International).
[126] Gordon SH and Tucker SA. 1997. Effect of light programme on broiler mortality, leg health and performance. British Poultry Science 38:S6-7.

[127] Knowles TG, Kestin SC, Haslam SM, et al. 2008. Leg disorders in broiler chickens: prevalence, risk factors and prevention. PLoS ONE 3(2):e1545. doi:10.1371/journal.pone.0001545. www.plosone.org/article/info:doi/10.1371/journal.pone.0001545. Accessed December 3, 2013.
[128] Lott BD, Branton SL, and May JD. 1996. The effect of photoperiod and nutrition on ascites incidence in broilers. Avian Diseases 40:788-91.
[129] Lewis P and Morris T. 2006. Poultry lighting: the theory and practice (Hampshire, U.K.: Northcot, p. 38).
[130] Gordon SH. 1994. Effects of daylength and increasing daylength programmes on broiler welfare and performance. World's Poultry Science Journal 50:269-82.
[131] Lewis PD, Danisman R, and Gous RM. 2009. Photoperiodic responses of broilers. I. Growth, feeding behaviour, breast meat yield, and testicular growth. British Poultry Science. 50(6):657-66.
[132] Schwean-Lardner K, Fancher BI, Gomis S, Van Kessel A, Dalal S, and Classen HL. 2013. Effect of day length on cause of mortality, leg health, and ocular health in broilers. Poultry Science 92:1-11.
[133] Alabama Cooperative Extension System. 2000. Controlling light in broiler production. The Alabama Poultry Engineering and Economics Newsletter, No. 6. www.aces.edu/dept/poultryventilation/documents/Nwsltr-6.pdf. Accessed December 3, 2013.
[134] Knowles TG, Kestin SC, Haslam SM, et al. 2008. Leg disorders in broiler chickens: prevalence, risk factors and prevention. PLoS ONE 3(2):e1545. doi:10.1371/journal.pone.0001545. www.plosone.org/article/info:doi/10.1371/journal.pone.0001545. Accessed December 3, 2013.
[135] Gordon SH. 1994. Effects of daylength and increasing daylength programmes on broiler welfare and performance. World's Poultry Science Journal 50:269-82.
[136] Prescott NB, Kristensen HH, and Wathes CM. 2004. Light. In: Weeks CA and Butterworth A (eds.), Measuring and Auditing Broiler Welfare (Wallingford, U.K.: CAB International).
[137] Lewis P and Morris T. 2006. Poultry lighting: the theory and practice (Hampshire, U.K.: Northcot, p. 39), citing: Lewis PD. 2001. Lighting regimes for broiler and egg production. In: Proceedings of XVII Latin American Poultry Congress, pp. 326-35.
[138] Classen HL and Riddell C. 1989. Photoperiodic effects on performance and leg abnormalities in broiler chickens. Poultry Science 68:873-9.
[139] Personal correspondence with Stephen Pretanik, director of Science and Technology, National Chicken Council, Washington, DC, June 11, 2008.
[140] National Chicken Council. 2010. National Chicken Council animal welfare guidelines and audit checklist. www.nationalchickencouncil.org/wp-content/uploads/2012/01/NCC-Animal-Welfare-Guidelines-2010-Revision-BROILERS.pdf. Accessed December 3, 2013.
[141] Prescott NB, Kristensen HH, and Wathes CM. 2004. Light. In: Weeks CA and Butterworth A (eds.), Measuring and Auditing Broiler Welfare (Wallingford, U.K.: CAB International).
[142] Knowles TG, Kestin SC, Haslam SM, et al. 2008. Leg disorders in broiler chickens: prevalence, risk factors and prevention. PLoS ONE 3(2):e1545. doi:10.1371/journal.pone.0001545. www.plosone.org/article/info:doi/10.1371/journal.pone.0001545. Accessed December 3, 2013.
[143] Gordon SH and Tucker SA. 1995. Effect of daylength on broiler welfare. British Poultry Science 36(5):844-5.
[144] Gordon SH and Tucker SA. 1997. Effect of light programme on broiler mortality, leg health and performance. British Poultry Science 38(Supplement):S6-7.
[145] Council Directive 2007/43/EC of 28 June 2007 laying down minimum rules for the protection of chickens kept for meat production. Official Journal of the European Union L 182/19. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:182:0019:0028:EN:PDF. Accessed December 3, 2013.
[146] Prescott NB, Kristensen HH, and Wathes CM. 2004. Light. In: Weeks CA and Butterworth A (eds.), Measuring and Auditing Broiler Welfare (Wallingford, U.K.: CAB International).
[147] Lacy MP. 2002. Broiler management. In: Bell DD and Weaver WD Jr (eds.), Commercial Chicken Meat and Egg Production, 5th Edition (Norwell, MA: Kluwer Academic Publishers, p. 856).
[148] Prescott NB, Kristensen HH, and Wathes CM. 2004. Light. In: Weeks CA and Butterworth A (eds.), Measuring and Auditing Broiler Welfare (Wallingford, U.K.: CAB International).

[149] Deep A, Schwean-Lardner K., Crowe TG, Fancher BI, and Classen HL. 2010. Effect of light intensity on broiler production, processing characteristics, and welfare. Poultry Science 89(11):2326-33.
[150] Alvino GM, Archer GS, and Mench JA. 2009. Behavioural time budgets of broiler chickens reared in varying light intensities. Applied Animal Behaviour Science 118(1-2):54-61.
[151] Newberry RC, Hunt JR, Gardiner EE. 1988. Influence of light intensity on behavior and performance of broiler chickens. Poultry Science 67:1020-5.
[152] Blatchford RA, Klasing KC, Shivaprasad HL, Wakenell PS, Archer GS, and Mench JA. 2009. The effect of light intensity on the behavior, eye and leg health, and immune function of broiler chickens. Poultry Science 88:20-8.
[153] Deep A, Schwean-Lardner K., Crowe TG, Fancher BI, and Classen HL. 2010. Effect of light intensity on broiler production, processing characteristics, and welfare. Poultry Science 89(11):2326-33.
[154] Newberry RC, Hunt JR, Gardiner EE. 1988. Influence of light intensity on behavior and performance of broiler chickens. Poultry Science 67:1020-5.
[155] Blatchford RA, Klasing KC, Shivaprasad HL, Wakenell PS, Archer GS, and Mench JA. 2009. The effect of light intensity on the behavior, eye and leg health, and immune function of broiler chickens. Poultry Science 88:20-8.
[156] Alvino GM, Archer GS, and Mench JA. 2009. Behavioural time budgets of broiler chickens reared in varying light intensities. Applied Animal Behaviour Science 118(1-2):54-61.
[157] Alvino GM, Blatchford RA, Archer GS, and Mench JA. 2009. Light intensity during rearing affects the behavioural synchrony and resting patterns of broiler chickens. British Poultry Science 50(3):275-83.
[158] Davis NJ, Prescott NB, Savory CJ, and Wathes CM. 1999. Preferences of growing fowls for different light intensities in relation to age, strain and behaviour. Animal Welfare 8:193-203.
[159] Dozier WA III, Lacy MP, and Vest LR. 2001. Broiler production and management. The University of Georgia College of Agricultural and Environmental Sciences, Cooperative Extension Service..
[160] Lacy MP. 2002. Broiler management. In: Bell DD and Weaver WD Jr (eds.), Commercial Chicken Meat and Egg Production, 5th Edition (Norwell, MA: Kluwer Academic Publishers).
[161] Carlile FS. 1984. Ammonia in poultry houses: a literature review. World's Poultry Science Journal 40:99-113.
[162] Bermudez AJ and Stewart-Brown. 2003. In: Saif YM, Barnes HJ, Glisson JR, Fadly AM, McDougald LR, and Swayne DE (eds.), Diseases of Poultry, 11th Edition (Ames, IA: Iowa State Press, p. 39).
[163] Banhazi TM, Seedorf J, Laffrique M, and Rutley DL. 2008. Identification of the risk factors for high airborne particle concentrations in broiler buildings using statistical modelling. Biosystems Engineering 101(1):100-10.
[164] Miles DM, Miller WW, Branton SL, Maslin WR, and Lott BD. 2006. Ocular responses to ammonia in broiler chickens. Avian Diseases 50(1):45-9.
[165] Olanrewaju HA, Miller WW, Maslin WR, et al. 2007 Interactive effects of ammonia and light intensity on ocular, fear and leg health in broiler chickens. International Journal of Poultry Science 6(10):762-9.
[166] Al-Mashhadani EH and Beck MM. 1985. Effect of atmospheric ammonia on the surface ultrastructure of the lung and trachea of broiler chicks. Poultry Science 64:2056-61.
[167] Berg CC. 1998. Foot-pad dermatitis in broilers and turkeys: prevalence, risk factors and prevention. Doctor's dissertation. Department of Animal Environment and Health, SLU. Acta Universitatis agriculturae Sueciae. Veterinaria 36, p. 16.
[168] Wathes CM. 1998. Aerial emissions from poultry production. World's Poultry Science Journal 54:241-51.
[169] Muirhead S. 1992. Ammonia control essential to maintenance of poultry health. Feedstuffs, April 13, p. 11.
[170] Kristensen HH and Wathes CM. 2000. Ammonia and poultry welfare: a review. World's Poultry Science Journal 56:235-45.
[171] Miles DM, Branton SL, and Lott BD. 2004. Atmospheric ammonia is detrimental to the performance of modern commercial broilers. Poultry Science 83(10):1650-4.
[172] Jones EKM, Wathes CM, and Webster AJF. 2003. Strength of motivation of broiler chickens to seek fresh air after exposure to atmospheric ammonia. British Poultry Science 44:S6-7.
[173] Jones EKM, Wathes CM, and Webster AJF. 2005. Avoidance of atmospheric ammonia by domestic fowl and the effect of early experience. Applied Animal Behaviour Science 90:293-308.

[174] Department for Environment, Food and Rural Affairs. 2002. Code of recommendations for the welfare of livestock: meat chickens and breeding chickens. www.gov.uk/government/publications/code-of-recommendations-for-the-welfare-of-livestock-meat-chickens-and-breeding-chickens. Accessed December 3, 2013.
[175] National Chicken Council. 2010. National Chicken Council animal welfare guidelines and audit checklist. www.nationalchickencouncil.org/wp-content/uploads/2012/01/NCC-Animal-Welfare-Guidelines-2010-Revision-BROILERS.pdf. Accessed December 3, 2013.
[176] Wheeler EF, Casey KD, Gates RS, et al. 2006. Ammonia emissions from twelve U.S. broiler chicken houses. Transactions of the American Society of Agricultural and Biological Engineers 49(5):1495-512.
[177] Wathes CM. 1998. Aerial emissions from poultry production. World's Poultry Science Journal 54:241-51.
[178] Scanes CG, Brant G, and Ensminger ME. 2004. Poultry Science, 4th Edition (Upper Saddle River, NJ: Pearson Prentice Hall, p. 260).
[179] Bell DD. 2002. Flock replacement programs and flock recycling. In: Bell DD and Weaver WD Jr (eds.), Commercial Chicken Meat and Egg Production, 5th Edition (Norwell, MA: Kluwer Academic Publishers, pp. 1075,1077).
[180] Bell DD. 2002. Flock replacement programs and flock recycling. In: Bell DD and Weaver WD Jr (eds.), Commercial Chicken Meat and Egg Production, 5th Edition (Norwell, MA: Kluwer Academic Publishers, p. 1077).
[181] Bell DD. 2002. Flock replacement programs and flock recycling. In: Bell DD and Weaver WD Jr (eds.), Commercial Chicken Meat and Egg Production, 5th Edition (Norwell, MA: Kluwer Academic Publishers, p. 1076).
[182] Bell DD. 2002. Flock replacement programs and flock recycling. In: Bell DD and Weaver WD Jr (eds.), Commercial Chicken Meat and Egg Production, 5th Edition (Norwell, MA: Kluwer Academic Publishers, pp.1076-7).
[183] Savory CJ, Maros K, and Rutter SM. 1993. Assessment of hunger in growing broiler breeders in relation to a commercial restricted feeding programme. Animal Welfare 2:131-52.
[184] De Jong IC and Guémené D. 2011. Major welfare issues in broiler breeders. World's Poultry Science Journal 67:73-82.
[185] Savory CJ, Maros K, and Rutter SM. 1993. Assessment of hunger in growing broiler breeders in relation to a commercial restricted feeding programme. Animal Welfare 2:131-52.
[186] Hocking PM. 2004. Measuring and auditing the welfare of broiler breeders. In: Weeks CA and Butterworth A (eds.), Measuring and Auditing Broiler Welfare (Wallingford, U.K.: CABI Publishing).
[187] De Jong IC and Jones B. 2006. Feed restriction and welfare in domestic birds. In: Bels V (ed.), Feeding in Domestic Vertebrates: From Structure to Behaviour (Wallingford, U.K.: CAB International, pp. 120-35).
[188] Decuypere E, Hocking PM, Tona K, et al. 2006. Broiler breeder paradox: a project report. Worlds Poultry Science Journal 62:443-53.
[189] EFSA Panel on Animal Health and Welfare. 2010. Scientific Opinion on welfare aspects of the management and housing of the grand-parent and parent stocks raised and kept for breeding purposes. EFSA Journal 8(7):1667, p. 23. www.efsa.europa.eu/fr/scdocs/doc/1667.pdf. Accessed December 3, 2013.
[190] Shane SM. 2007. Progress in refining standards, audits. Watt Poultry USA, October, pp. 34-7.
[191] Coon CN. 2002. Feeding broiler breeders. In: Bell DD and Weaver WD Jr (eds.), Commercial Chicken Meat and Egg Production, 5th Edition (Norwell, MA: Kluwer Academic Publishers).
[192] Mench JA. 1993. Problems associated with broiler breeder management. In: Savory CJ and Hughes BO (eds.), Proceedings of the 4th European Symposium on Poultry Welfare (Edinburgh, U.K., pp. 195-207).
[193] Hocking PM. 2004. Measuring and auditing the welfare of broiler breeders. In: Weeks CA and Butterworth A (eds.), Measuring and Auditing Broiler Welfare (Wallingford, U.K.: CABI Publishing).
[194] Hocking PM. 2004. Measuring and auditing the welfare of broiler breeders. In: Weeks CA and Butterworth A (eds.), Measuring and Auditing Broiler Welfare (Wallingford, U.K.: CABI Publishing).
[195] Burkhart CA, Cherry JA, Van Krey HP, and Siegel PB. 1983. Genetic selection for growth rate alters hypothalamic satiety mechanisms in chickens. Behavior Genetics 13(3):295-300.

[196] Buckley LA, McMillan LM, Sandilands V, Tolkamp BJ, Hocking PM and D'Eath RB. 2011. Too hungry to learn? Hungry broiler breeders fail to learn a Y-maze food quantity discrimination task. Animal Welfare 20(4):469-81.
[197] Hocking PM, Maxwell MH, and Mitchell MA. 1996. Relationships between the degree of food restriction and welfare indices in broiler breeder females. British Poultry Science 37(2):263-78.
[198] De Jong IC and Guémené D. 2011. Major welfare issues in broiler breeders. World's Poultry Science Journal 67:73-82.
[199] Savory CJ, Maros K, and Rutter SM. 1993. Assessment of hunger in growing broiler breeders in relation to a commercial restricted feeding programme. Animal Welfare 2:131-52.
[200] De Jong IC and Jones B. 2006. Feed restriction and welfare in domestic birds. In: Bels V (ed.), Feeding in Domestic Vertebrates: From Structure to Behaviour (Wallingford, U.K.: CAB International, pp. 120-35).
[201] Mench JA. 2002. Broiler breeders: feed restriction and welfare. World's Poultry Science Journal 58(1):23-9.
[202] Savory CJ, Maros K, and Rutter SM. 1993. Assessment of hunger in growing broiler breeders in relation to a commercial restricted feeding programme. Animal Welfare 2:131-52.
[203] Savory CJ, Wood-Gush DGM, and Duncan IJH. 1978. Feeding behaviour in a population of domestic fowls in the wild. Applied Animal Ethology 4:13-27.
[204] Dawkins MS. 1989. Time budgets in Red Junglefowl as a baseline for the assessment of welfare in domestic fowl. Applied Animal Behaviour Science 24:77-80.
[205] EFSA Panel on Animal Health and Welfare. 2010. Scientific Opinion on welfare aspects of the management and housing of the grand-parent and parent stocks raised and kept for breeding purposes. EFSA Journal 8(7):1667, p. 23-4. www.efsa.europa.eu/fr/scdocs/doc/1667.pdf. Accessed December 3, 2013.
[206] Savory CJ and Maros K. 1993. Influence of degree of food restriction, age and time of day on behaviour of broiler breeder chickens. Behavioural Processes 29:179-90.
[207] EFSA Panel on Animal Health and Welfare. 2010. Scientific Opinion on welfare aspects of the management and housing of the grand-parent and parent stocks raised and kept for breeding purposes. EFSA Journal 8(7):1667, p. 23. www.efsa.europa.eu/fr/scdocs/doc/1667.pdf. Accessed December 3, 2013.
[208] Hocking PM, Maxwell MH, and Mitchell MA. 1996. Relationships between the degree of food restriction and welfare indices in broiler breeder females. British Poultry Science 37(2):263-78.
[209] Jones EKM, Zaczek V, MacLeod M, and Hocking PM. 2004. Genotype, dietary manipulation and food allocation affect indices of welfare in broiler breeders. British Poultry Science 45(6):725-37.
[210] Merlet F, Puterflam J, Faure JM, Hocking PM, Magnusson MS, and Picard M. 2005. Detection and comparison of time patterns of behaviours of two broiler breeder genotypes fed ad libitum and two levels of feed restriction. Applied Animal Behaviour Science 94(3/4):255-71.
[211] Hocking PM. 2009. Feed restriction. In: Hocking PM (ed.), Biology of Breeding poultry. Poultry Science Symposium Series, Vol. 29 (Wallingford, U.K.: CAB International, pp.307-30).
[212] Scientific Committee on Animal Health and Animal Welfare. 2000. The welfare of chickens kept for meat production (broilers). For the European Commission, p. 84. http://ec.europa.eu/food/fs/sc/scah/out39_en.pdf. Accessed December 3, 2013.
[213] de Jong IC, Enting H, van Voorst A, and Blokhuis HJ. 2005. Do low-density diets improve broiler breeder welfare during rearing and laying? Poultry Science 84:194-203.
[214] Zuidhof MJ, Robinson FE, Feddes JJR, and Hardin RT. 1995. The effects of nutrient dilution on the well-being and performance of female broiler breeders. Poultry Science 74(3):441-56.
[215] de Jong IC, Enting H, van Voorst A, and Blokhuis HJ. 2005. Do low-density diets improve broiler breeder welfare during rearing and laying? Poultry Science 84:194-203.
[216] de Jong IC and Jones B. 2006. Feed restriction and welfare in domestic birds. In: Bels V (ed.), Feeding in Domestic Vertebrates: From Structure to Behaviour (Wallingford, U.K.: CAB International, pp. 120-35).
[217] Decuypere E, Hocking PM, Tona K, et al. 2006. Broiler breeder paradox: a project report. Worlds Poultry Science Journal 62:443-53.
[218] Jones EKM, Zaczek V, MacLeod M, and Hocking PM. 2004. Genotype, dietary manipulation and food allocation affect indices of welfare in broiler breeders. British Poultry Science 45(6):725-37.
[219] Brake J. 1998. Equipment design for breeding flocks. Poultry Science 77:1833-41.

[220] Wilson JL. 1999. Hatchery/breeder tip: managing roosters for hatchability. The University of Georgia College of Agricultural and Environmental Sciences, Cooperative Extension Service. www.poultry.uga.edu/extension/tips/documents/05%201999%20HB%20tip%20J%20L%20W.pdf. Accessed December 3, 2013.
[221] Millman ST, Duncan IJH, and Widowski TM. 2000. Male broiler breeder fowl display high levels of aggression toward females. Poultry Science 79:1233-41.
[222] Millman ST and Duncan IJH. 2000. Effect of male-to-male aggressiveness and feed-restriction during rearing on sexual behaviour and aggressiveness towards females by male domestic fowl. Applied Animal Behaviour Science 70:63-82.
[223] Millman ST, Duncan IJH, and Widowski TM. 2000. Male broiler breeder fowl display high levels of aggression toward females. Poultry Science 79:1233-41.
[224] Millman ST, Duncan IJH, and Widowski TM. 2000. Male broiler breeder fowl display high levels of aggression toward females. Poultry Science 79:1233-41, citing: Mench JA. 1993. Problems associated with broiler breeder management. In: Savory CJ and Hughes BO (eds.), Proceedings of the 4th European Symposium on Poultry Welfare (Potters Bar, U.K.: Universities Federation for Animal Welfare, pp. 195-207).
[225] Brake J. 1998. Equipment design for breeding flocks. Poultry Science 77:1833-41.
[226] Mench JA. 1993. Problems associated with broiler breeder management. In: Savory CJ and Hughes BO (eds.), Proceedings of the 4th European Symposium on Poultry Welfare (Edinburgh, U.K., pp. 195-207).
[227] Mench JA. 1988. The development of aggressive behavior in male broiler chicks: a comparison with laying-type males and the effects of feed restriction. Applied Animal Behaviour Science 21:233-42.
[228] Millman ST and Duncan IJH. 2000. Effect of male-to-male aggressiveness and feed-restriction during rearing on sexual behaviour and aggressiveness towards females by male domestic fowl. Applied Animal Behaviour Science 70:63-82.
[229] Millman ST and Duncan IJH. 2000. Effect of male-to-male aggressiveness and feed-restriction during rearing on sexual behaviour and aggressiveness towards females by male domestic fowl. Applied Animal Behaviour Science 70:63-82.
[230] De Jong IC, Wolthuis-Fillerup M, and van Emous RA. 2009. Development of sexual behaviour in commercially-housed broiler breeders after mixing. British Poultry Science 50(2):151-60.
[231] Mauldin JM and Morrison T III. 2002. Equipment for hatcheries. In: Bell DD and Weaver WD Jr (eds.), Commercial Chicken Meat and Egg Production, 5th Edition (Norwell, MA: Kluwer Academic Publishers).
[232] Duncan IJH. 2004. Welfare problems of poultry. In: Benson GJ and Rollin BE (eds.), The Well-Being of Farm Animals: Challenges and Solutions (Ames, IA: Blackwell Publishing).
[233] Meijerhof R. 2002. Managing the breeding flock. In: Bell DD and Weaver WD (eds.), Commercial Chicken Meat and Egg Production, 5th Edition (Norwell, MA: Kluwer Academic Publishers).
[234] Duncan IJH. 2004. Welfare problems of poultry. In: Benson GJ and Rollin BE (eds.), The Well-Being of Farm Animals: Challenges and Solutions (Ames, IA: Blackwell Publishing).
[235] Gentle MJ and Hunter LH. 1988. Neural consequences of partial toe amputation in chickens. Research in Veterinary Science 45:374-6.
[236] Fraser D, Mench J, and Millman S. 2001. Farm animals and their welfare in 2000. In: Salem DJ and Rowan AN (eds.), The State of the Animals: 2001 (Washington, DC: Humane Society Press).
[237] Cheng H. 2006. Morphopathological changes and pain in beak trimmed laying hens. World's Poultry Science Journal 62:41-52.
[238] Duncan IJH. 2004. Welfare problems of poultry. In: Benson GJ and Rollin BE (eds.), The Well-Being of Farm Animals: Challenges and Solutions (Ames, IA: Blackwell Publishing).
[239] Gentle MJ and McKeegan DEF. 2007. Evaluation of the effects of infrared beak trimming in broiler breeder chicks. The Veterinary Record 160:145-8.
[240] Cheng H. 2006. Morphopathological changes and pain in beak trimmed laying hens. World's Poultry Science Journal 62:41-52.
[241] Mauldin JM and Morrison T III. 2002. Equipment for hatcheries. In: Bell DD and Weaver WD Jr (eds.), Commercial Chicken Meat and Egg Production, 5th Edition (Norwell, MA: Kluwer Academic Publishers).
[242] Gentle MJ and McKeegan DEF. 2007. Evaluation of the effects of infrared beak trimming in broiler breeder chicks. Veterinary Record 160(5):145-8.

[243] Mench JA. 1992. The welfare of poultry in modern production systems. Poultry Science Reviews 4:107-28.
[244] Duncan IJH. 2001. Animal welfare issues in the poultry industry: is there a lesson to be learned? Journal of Applied Animal Welfare Science 4(3):207-21.
[245] Gentle MJ, Waddington D, Hunter LN, and Jones RB. 1990. Behavioural evidence for persistent pain following partial beak amputation in chickens. Applied Animal Behaviour Science 27:149-57.
[246] Hughes BO and Gentle MJ. 1995. Beak trimming of poultry: its implications for welfare. World's Poultry Science Journal 51:51-61.
[247] Cheng H. 2006. Morphopathological changes and pain in beak trimmed laying hens. World's Poultry Science Journal 62:41-52.
[248] Gentle MJ. 1986. Neuroma formation following partial beak amputation (beak trimming) in the chicken. Research in Veterinary Science 41:383-5.
[249] Gentle M and Wilson S. 2004. Pain and the laying hen. In: Perry GC (ed.), Welfare of the Laying Hen (Wallingford, U.K.: CABI Publishing).
[250] Cheng H. 2006. Morphopathological changes and pain in beak trimmed laying hens. World's Poultry Science Journal 62:41-52.
[251] Gentle MJ and Hunter LH. 1988. Neural consequences of partial toe amputation in chickens. Research in Veterinary Science 45:374-6.
[252] Scanes CG, Brant G, and Ensminger ME. 2004. Poultry Science, 4th Edition (Upper Saddle River, NJ: Pearson Prentice Hall, p. 260).
[253] U.S. Department of Agriculture. 2012. 2007 Census Ag Atlas Maps - Livestock and Animals. Number of Broilers and Other Meat-Type Chickens Sold: 2007. www.agcensus.usda.gov/Publications/2007/Online_Highlights/Ag_Atlas_Maps/Livestock_and_Animals/Livestock,_Poultry_and_Other_Animals/07-M161.php. Accessed December 3, 2013.
[254] Ritz CW, Webster AB, and Czarick M III. 2005. Evaluation of hot weather thermal environment and incidence of mortality associated with broiler live haul. Journal of Applied Poultry Research 14(3):594-602.
[255] Bayliss PA and Hinton MH. 1990. Transportation of broilers with special reference to mortality rates. Applied Animal Behaviour Science 28:93-118.
[256] Nijdam E, Arens P, Lambooij E, Decuypere E, and Stegeman JA. 2004. Factors influencing bruises and mortality of broilers during catching, transport, and lairage. Poultry Science 83:1610-5.
[257] Ramasamy S, Benson ER, and Van Wicklen GL. 2004. Efficiency of a commercial mechanical chicken catching system. Journal of Applied Poultry Research 13:19-28.
[258] Jones RB. 1992. The nature of handling immediately prior to test affects tonic immobility fear reactions in laying hens and broilers. Applied Animal Behaviour Science 34:247-54.
[259] Knowles TG and Broom DM. 1990. The handling and transport of broilers and spent hens. Applied Animal Behaviour Science 28:75-91, citing: Duncan IJH and Kite VG. 1987. Report for 1986-1987. AFRC Institute of Animal Physiology and Genetics Research, Edinburgh Research Station, Edinburgh, pp. 30-6.
[260] Kannan G and Mench JA. 1996. Influence of different handling methods and crating periods on plasma corticosterone concentrations in broilers. British Poultry Science 37:21-31.
[261] Voslarova E, Chloupek P, Vosmerova P, Chloupek J, Bedanova I, and Vecerek V. 2011. Time course changes in selected biochemical indices of broilers in response to pretransport handling. Poultry Science 90(10):2144-52.
[262] Weeks CA. 2007. Poultry handling and transport. In: Grandin T (ed.), Livestock Handling and Transport, 3rd Edition (Wallingford, U.K.: CAB International).
[263] Ritz CW, Webster AB, and Czarick M III. 2005. Evaluation of hot weather thermal environment and incidence of mortality associated with broiler live haul. Journal of Applied Poultry Research 14(3):594-602.
[264] Lacy MP and Czarick M. 1998. Mechanical harvesting of broilers. Poultry Science 77:1794-7.
[265] Metheringham J and Hubrecht R. 1996. Poultry in transit—a cause for concern? British Veterinary Journal 152:247-9.
[266] Gregory NG and Wilkins LJ. 1992. Skeletal damage and bone defects during catching and processing. In: Whitehead CC (ed.), Bone Biology and Skeletal Disorders in Poultry (Abingdon, U.K.: Carfax Publishing).
[267] Sams AR. 2001. Preslaughter factors affecting poultry meat quality. In: Sams AR (ed.), Poultry Meat Processing (Washington, DC: CRC Press, p. 14).

[268] Ritz CW, Webster AB, and Czarick M III. 2005. Evaluation of hot weather thermal environment and incidence of mortality associated with broiler live haul. Journal of Applied Poultry Research 14(3):594-602.
[269] Gregory NG. 1998. Animal Welfare and Meat Science (Wallingford, U.K.: CABI Publishing, pp. 183-94).
[270] Mitchell MA, Kettlewell PJ, and Maxwell MH. 1992. Indicators of physiological stress in broiler chickens during road transportation. Animal Welfare 1:91-103.
[271] Freeman BM, Kettlewell PJ, Manning ACC, and Berry PS. 1984. Stress of transportation for broilers. The Veterinary Record 114:286-7.
[272] Ondrašovičová O, Saba L, Šmirjáková S, et al. 2008. Effects of vehicle-road transport on blood profile in broiler chickens. Medycyna Weterynaryjna 64(3):292-3.
[273] Vošmerová P, Bedáňová I, Chloupek P, Chloupek J, Suchý Jr. P, and Večerek V. 2010. Transport-induced changes in selected biochemical indices in broilers as affected by ambient temperatures. Acta Veterinaria Brno, 79(Supplement 9):S41-6.
[274] Mench JA. 1992. The welfare of poultry in modern production systems. Poultry Science Reviews 4:107-28.
[275] Weeks CA. 2007. Poultry handling and transport. In: Grandin T (ed.), Livestock Handling and Transport, 3rd Edition (Wallingford, U.K.: CAB International).
[276] Duncan IJH. 1989. The assessment of welfare during the handling and transport of broilers. In: Faure JM and Mills AD (eds.), Proceedings of the Third European Symposium on Poultry Welfare (Tours, France: French Branch of the World Poultry Science Association, pp. 93-107).
[277] Delezie E, Swennen Q, Buyse J, and Decuypere E. 2007. The effect of feed withdrawal and crating density in transit on metabolism and meat quality of broilers at slaughter weight. Poultry Science 86(7):1414-23.
[278] Nijdam E, Zailan ARM, van Eck JHH, Decuypere E, and Stegeman JA. 2006. Pathological features in dead on arrival broilers with special reference to heart disorders. Poultry Science 85:1303-8.
[279] Gregory NG and Austin SD. 1992. Causes of trauma in broilers arriving dead at poultry processing plants. The Veterinary Record 131:501-3.
[280] Gregory NG and Austin SD. 1992. Causes of trauma in broilers arriving dead at poultry processing plants. The Veterinary Record 131:501-3.
[281] Ritz CW, Webster AB, and Czarick M III. 2005. Evaluation of hot weather thermal environment and incidence of mortality associated with broiler live haul. Journal of Applied Poultry Research 14(3):594-602.
[282] Tapper J. 2012. Maple Lodge Farms faces 60 criminal charges as thousands of chickens perish. The Toronto Star, January 8. www.thestar.com/news/gta/2012/01/08/maple_lodge_farms_faces_60_criminal_charges_as_thousands_of_chickens_perish.html. Accessed December 3, 2013.
[283] Petracci M, Bianchi M, Cavani C, Gaspari P, and Lavazza A. 2006. Preslaughter mortality in broiler chickens, turkeys, and spent hens under commercial slaughtering. Poultry Science 85(9):1660-4.
[284] Hunter RR, Mitchell MA, and Matheu C. 1997. Distribution of 'dead on arrivals' within the bio-load on commercial broiler transporters: correlation with climate conditions and ventilation regimen. British Poultry Science 38(Supplement):S7-9.
[285] Watts JM, Graff LJ, Strawford ML, et al. 2011. Heat and moisture production by broilers during simulated cold weather transport. Poultry Science 90(9):1890-9.
[286] Knezacek TD, Olkowski AA, Kettlewell PJ, Mitchell MA, and Classen HL. 2010. Temperature gradients in trailers and changes in broiler rectal and core body temperature during winter transportation in Saskatchewan, Canadian Journal of Animal Science 90: 321-30.
[287] Warriss PD, Bevis EA, Brown SN, and Edwards JE. 1992. Longer journeys to processing plants are associated with higher mortality in broiler chickens. British Poultry Science 33:201-6.
[288] Nijdam E, Arens P, Lambooij E, Decuypere E, and Stegeman JA. 2004. Factors influencing bruises and mortality of broilers during catching, transport, and lairage. Poultry Science 83:1610-5.
[289] Ekstrand C. 1998. An observational cohort study of the effects of catching method on carcase rejection rates in broilers. Animal Welfare 7:87-96.
[290] Chauvin C, Hillion S, Balaine L, et al. 2011. Factors associated with mortality of broilers during transport to slaughterhouse. Animal 5(2):287-93.
[291] Petracci M, Bianchi M, Cavani C, Gaspari P, and Lavazza A. 2006. Preslaughter mortality in broiler chickens, turkeys, and spent hens under commercial slaughtering. Poultry Science 85(9):1660-4.

[292] Vieira FMC, Silva IJO, Barbosa Filho JAD, Vieira AMC, and Broom DM. 2011. Preslaughter mortality of broilers in relation to lairage and season in a subtropical climate. Poultry Science 90(10):2127-33.
[293] Haslam SM, Knowles TG, Brown SN, et al. 2008. Prevalence and factors associated with it, of birds dead on arrival at the slaughterhouse and other rejection conditions in broiler chickens. British Poultry Science 49(6):685-96.
[294] Drain ME, Whiting TL, Rasali DP, and D'Angiolo VA. 2007. Warm weather transport of broiler chickens in Manitoba. I. Farm management factors associated with death loss in transit to slaughter. Canadian Veterinary Journal 48(1):76-80.
[295] Vecerek V, Grbalova S, Voslarova E, Janackova B, and Malena M. 2006. Effects of travel distance and the season of the year on death rates of broilers transported to poultry processing plants. Poultry Science 85(11):1881-4.
[296] Bianchi M, Petracci M, and Cavani C. 2005. Effects of transport and lairage on mortality, liveweight loss and carcass quality in broiler chickens. Italian Journal of Animal Science 4(Supplement 2):516-8.
[297] Warriss PD, Pagazaurtundua A, and Brown SN. 2005. Relationship between maximum daily temperature and mortality of broiler chickens during transport and lairage. British Poultry Science 46(6):647-51.
[298] Ritz CW, Webster AB, and Czarick M III. 2005. Evaluation of hot weather thermal environment and incidence of mortality associated with broiler live haul. Journal of Applied Poultry Research 14(3):594-602.
[299] Ritz CW, Webster AB, and Czarick M III. 2005. Evaluation of hot weather thermal environment and incidence of mortality associated with broiler live haul. Journal of Applied Poultry Research 14(3):594-602.
[300] Nijdam E, Arens P, Lambooij E, Decuypere E, and Stegeman JA. 2004. Factors influencing bruises and mortality of broilers during catching, transport, and lairage. Poultry Science 83:1610-5.
[301] Vieira FMC, Silva IJO, Barbosa Filho JAD, Vieira AMC, and Broom DM. 2011. Preslaughter mortality of broilers in relation to lairage and season in a subtropical climate. Poultry Science 90(10):2127-33.
[302] Oba A, de Almeida M, Pinheiro JW, et al. 2009. The effect of management of transport and lairage conditions on broiler chicken breast meat quality and DOA (death on arrival). Brazilian Archives of Biology and Technology 52(Special Number):205-11.
[303] Vecerek V, Grbalova S, Voslarova E, Janackova B, and Malena M. 2006. Effects of travel distance and the season of the year on death rates of broilers transported to poultry processing plants. Poultry Science 85(11):1881-4.
[304] Bianchi M, Petracci M, and Cavani C. 2005. Effects of transport and lairage on mortality, liveweight loss and carcass quality in broiler chickens. Italian Journal of Animal Science 4(Supplement 2):516-8.
[305] Nijdam E, Arens P, Lambooij E, Decuypere E, and Stegeman JA. 2004. Factors influencing bruises and mortality of broilers during catching, transport, and lairage. Poultry Science 83:1610-5.
[306] Nijdam E, Arens P, Lambooij E, Decuypere E, and Stegeman JA. 2004. Factors influencing bruises and mortality of broilers during catching, transport, and lairage. Poultry Science 83:1610-5.
[307] Vieira FMC, Silva IJO, Barbosa Filho JAD, Vieira AMC, and Broom DM. 2011. Preslaughter mortality of broilers in relation to lairage and season in a subtropical climate. Poultry Science 90(10):2127-33.
[308] Vecerek V, Grbalova S, Voslarova E, Janackova B, and Malena M. 2006. Effects of travel distance and the season of the year on death rates of broilers transported to poultry processing plants. Poultry Science 85(11):1881-4.
[309] Warriss PD, Pagazaurtundua A, and Brown SN. 2005. Relationship between maximum daily temperature and mortality of broiler chickens during transport and lairage. British Poultry Science 46(6):647-51.
[310] Whiting TL, Drain ME, and Rasali DP. 2007. Warm weather transport of broiler chickens in Manitoba. II. Truck management factors associated with death loss in transit to slaughter. Canadian Veterinary Journal 48:148-54.
[311] Nijdam E, Arens P, Lambooij E, Decuypere E, and Stegeman JA. 2004. Factors influencing bruises and mortality of broilers during catching, transport, and lairage. Poultry Science 83:1610-5.
[312] Vieira FMC, Silva IJO, Barbosa Filho JAD, Vieira AMC, and Broom DM. 2011. Preslaughter mortality of broilers in relation to lairage and season in a subtropical climate. Poultry Science 90(10):2127-33.
[313] Whiting TL, Drain ME, and Rasali DP. 2007. Warm weather transport of broiler chickens in Manitoba. II. Truck management factors associated with death loss in transit to slaughter. Canadian Veterinary Journal 48:148-54.

[314] Nijdam E, Arens P, Lambooij E, Decuypere E, and Stegeman JA. 2004. Factors influencing bruises and mortality of broilers during catching, transport, and lairage. Poultry Science 83:1610-5.
[315] Drain ME, Whiting TL, Rasali DP, and D'Angiolo VA. 2007. Warm weather transport of broiler chickens in Manitoba. I. Farm management factors associated with death loss in transit to slaughter. Canadian Veterinary Journal 48(1):76-80.
[316] Chauvin C, Hillion S, Balaine L, et al. 2011. Factors associated with mortality of broilers during transport to slaughterhouse. Animal 5(2):287-93.
[317] Ritz CW, Webster AB, and Czarick M III. 2005. Evaluation of hot weather thermal environment and incidence of mortality associated with broiler live haul. Journal of Applied Poultry Research 14(3):594-602.
[318] European Food Safety Authority. 2011. Scientific opinion concerning the welfare of animals during transport. EFSA Journal 9(1):1966, p. 51. www.efsa.europa.eu/en/efsajournal/doc/1966.pdf. Accessed December 3, 2013.
[319] Vieira FMC, Silva IJO, Barbosa Filho JAD, Vieira AMC, and Broom DM. 2011. Preslaughter mortality of broilers in relation to lairage and season in a subtropical climate. Poultry Science 90(10):2127-33.
[320] Gentle MJ and Tilston VL. 2000. Nociceptors in the legs of poultry: implications for potential pain in pre-slaughter shackling. Animal Welfare 9:227-36.
[321] Gentle MJ. 1992. Ankle joint (artc. intertarsalis) receptors in the domestic fowl. Neuroscience 49(4):991-1000.
[322] European Food Safety Authority. 2004. Scientific report of the Scientific Panel for Animal Health and Welfare on a request from the Commission related to welfare aspects of animal stunning and killing methods, pp. 125-6. www.efsa.europa.eu/cs/BlobServer/Scientific_Opinion/opinion_ahaw_02_ej45_stunning_report_v2_en1,1.pdf. Accessed December 3, 2013.
[323] Danbury TC, Weeks CA, Chambers JP, Waterman-Pearson AE, and Kestin SC. 2000. Self-selection of the analgesic drug carprofen by lame broiler chickens. The Veterinary Record 146(11):307-11.
[324] Raj ABM. 2004. Stunning and slaughter of poultry. In: Mead GC (ed.), Poultry Meat Processing and Quality (Cambridge, U.K.: Woodhead Publishing Ltd.).
[325] EFSA Panel on Animal Health and Welfare. 2010. Scientific Opinion on welfare aspects of the management and housing of the grand-parent and parent stocks raised and kept for breeding purposes. EFSA Journal 8(7):1667, p. 31. www.efsa.europa.eu/fr/scdocs/doc/1667.pdf. Accessed December 3, 2013.
[326] Kannan G and Mench JA. 1996. Influence of different handling methods and crating periods on plasma corticosterone concentrations in broilers. British Poultry Science 37(1):21-31.
[327] Debut M, Berri C, Arnould C, et al. 2005. Behavioural and physiological responses of three chicken breeds to pre-slaughter shackling and acute heat stress. British Poultry Science 46(5):527-35.
[328] Kannan G, Heath JL, Wabeck CJ, and Mench JA. 1997. Shackling of broilers: effects on stress responses and breast meat quality. British Poultry Science 38(4):323-32.
[329] Bedanova I, Voslarova E, Chloupek P, et al. 2007. Stress in broilers resulting from shackling. Poultry Science 86(6):1065-9.
[330] Satterlee DG, Parker LH, Castille SA, Cadd GG, and Jones RB. 2000. Struggling behavior in shackled male and female broiler chickens. Poultry Science 79:652-5.
[331] Kannan G, Heath JL, Wabeck CJ, and Mench JA. 1997. Shackling of broilers: effects on stress responses and breast meat quality. British Poultry Science 38(4):323-32.
[332] European Food Safety Authority. 2004. Opinion of the Scientific Panel on Animal Health and Welfare (AHAW) on a request from the Commission related to welfare aspects of the main systems of stunning and killing the main commercial species of animals. www.efsa.europa.eu/EFSA/efsa_locale-1178620753812_1178620775454.htm. Accessed December 3, 2013.
[333] U.S. Department of Agriculture Food Safety and Inspection Service. 2005. Treatment of live poultry before slaughter; notice. September 28. Federal Register 70(187):56624-26.
[334] Bilgili SF. 1999. Recent advances in electrical stunning. Poultry Science 78:282-6.
[335] Gregory NG and Bell JC. 1987. Duration of wing flapping in chickens shackled before slaughter. The Veterinary Record 121:567-9.

[336] European Food Safety Authority. 2004. Opinion of the Scientific Panel for Animal Health and Welfare on a request from the Commission related to welfare aspects of animal stunning and killing the main commercial species of animals. The EFSA Journal 45:1-29. www.efsa.europa.eu/cs/BlobServer/Scientific_Opinion/opinion_ahaw_02_ej45_stunning_report_v2_en1,1.pdf. Accessed December 3, 2013.
[337] Sparrey JM, Kettlewell PJ, Paice MER, and Whetlor WC. 1993. Development of a constant current water bath stunner for poultry processing. Journal of Agricultural Engineering Research 56:267-74.
[338] Schütt-Abraham I, Wormuth HJ, and Fessel J. 1983. Electrical stunning of poultry in view of animal welfare and meat production. In: Eikelenboom G (ed.), Stunning of Animals for Slaughter (The Hague: Martinus Nijhoff Publishers).
[339] Gazdziak S. 2007. Kill floor improvements: automation on the poultry kill and eviscerating lines is increasing efficiency and product quality. The National Provisioner, December, pp. 66, 68.
[340] Rao MA Knowles TG, and Wotton SB. 2013. The effect of pre-stun shocks in electrical water-bath stunners on carcase and meat quality in broilers. Animal Welfare 22(1):79-84.
[341] Raj ABM. 2004. Stunning and slaughter of poultry. In: Mead GC (ed.), Poultry Meat Processing and Quality (Cambridge, U.K.: Woodhead Publishing Ltd.).
[342] Bilgili SF. 1999. Recent advances in electrical stunning. Poultry Science 78:282-6.
[343] Raj ABM. 2004. Stunning and slaughter of poultry. In: Mead GC (ed.), Poultry Meat Processing and Quality (Cambridge, U.K.: Woodhead Publishing Ltd.).
[344] World Organization for Animal Health. 2012. Terrestrial Animal Health Code, 22nd Edition. www.oie.int/en/international-standard-setting/terrestrial-code/. Accessed December 3, 2013.
[345] World Organization for Animal Health. 2012. Terrestrial Animal Health Code, Chapter 7.5, Slaughter of Animals. www.oie.int/index.php?id=169&L=0&htmfile=chapitre_1.7.5.htm. Accessed December 3, 2013.
[346] Nunes F. 2007. How to avoid bruising during electrical poultry stunning. Meatingplace.com, May.
[347] Bilgili SF. 1999. Recent advances in electrical stunning. Poultry Science 78(2):282-6.
[348] Gazdziak S. 2007. Kill floor improvements: automation on the poultry kill and eviscerating lines is increasing efficiency and product quality. The National Provisioner, December, pp. 66, 68.
[349] Bilgili SF. 1999. Recent advances in electrical stunning. Poultry Science 78(2):282-6.
[350] Nunes F. 2007. How to avoid bruising during electrical poultry stunning. Meatingplace.com, May.
[351] Raj ABM, O'Callaghan M, and Hughes SI. 2006. The effects of amount and frequency of pulsed direct current used in water bath stunning and of slaughter methods on spontaneous electroencephalograms in broilers. Animal Welfare 15:19-24.
[352] Raj ABM, O'Callaghan M, and Knowles TG. 2006. The effects of amount and frequency of alternating current used in water bath stunning and of slaughter methods on electroencephalograms in broilers. Animal Welfare 15:7-18.
[353] Raj ABM. 2004. Stunning and slaughter of poultry. In: Mead GC (ed.), Poultry Meat Processing and Quality (Cambridge, U.K.: Woodhead Publishing Ltd.).
[354] Heath GBS, Watt DJ, Waite PR, and Ormond JM. 1981. Observations on poultry slaughter. The Veterinary Record 108:97-9.
[355] Shane SM. 2005. Future of gas stunning. Watt Poultry USA, April, pp. 16-23.
[356] National Institute for Animal Agriculture. 2007. U.S. broiler health shows slight decline. Poultry Health Report, Fall/Winter. www.thepoultrysite.com/articles/970/us-broiler-health-shows-slight-decline. Accessed December 3, 2013.
[357] Gregory NG. 1986. The physiology of electrical stunning and slaughter. In: Humane Slaughter of Animals for Food Symposium (Hertfordshire, U.K.: Universities Federation for Animal Welfare).
[358] Raj ABM. 2004. Stunning and slaughter of poultry. In: Mead GC (ed.), Poultry Meat Processing and Quality (Cambridge, U.K.: Woodhead Publishing Ltd.).
[359] Heath GBS, Watt DJ, Waite PR, and Ormond JM. 1981. Observations on poultry slaughter. The Veterinary Record 108:97-9.
[360] Heath GBS, Watt DJ, Waite PR, and Meakins PA. 1983. Further observations on the slaughter of poultry. British Veterinary Journal 139:285-90.

[361] Raj ABM. 2004. Stunning and slaughter of poultry. In: Mead GC (ed.), Poultry Meat Processing and Quality (Cambridge, U.K.: Woodhead Publishing Ltd.).
[362] Shane SM. 2005. Future of gas stunning. Watt Poultry USA, April, pp. 16-23.
[363] U.S. Department of Agriculture Food Safety and Inspection Service. 2005. Poultry Slaughter Inspection Training. Poultry postmortem inspection, p. 15. www.fsis.usda.gov/PDF/PSIT_PostMortem.pdf. Accessed December 3, 2013.
[364] U.S. Department of Agriculture National Agricultural Statistics Service. 2013. Poultry slaughter: 2012 annual summary. http://usda01.library.cornell.edu/usda/current/PoulSlauSu/PoulSlauSu-02-25-2013.pdf. Accessed December 3, 2013.
[365] Raj M. 1998. Welfare during stunning and slaughter of poultry. Poultry Science 77:1815-9.
[366] Dawkins MS and Layton R. 2012. Breeding for better welfare: genetic goals for broiler chickens and their parents. Animal Welfare 21:147-55.
[367] Balog JM, Bayyari GR, Rath NC, Huff WE, and Anthony NB. 1997. Effect of intermittent activity on broiler production parameters. Poultry Science 76:6-12.
[368] Balog JM, Bayyari GR, Rath NC, Huff WE, and Anthony NB. 1997. Effect of intermittent activity on broiler production parameters. Poultry Science 76:6-12.
[369] Ventura BA, Siewerdt F, and Estevez I. 2012. Access to barrier perches improves behavior repertoire in broilers. PLoS ONE 7(1):e29826. www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0029826. Accessed December 3, 2013.
[370] Lacy MP and Czarick M. 1998. Mechanical harvesting of broilers. Poultry Science 77:1794-7.
[371] Delezie E, Lips D, Lips R, and Decuypere E. 2005. Mechanical catching of broiler chickens is a viable alternative for manual catching from an animal welfare point of view. Animal Science Papers and Reports 23(Supplement 1):257-64
[372] Kettlewell PJ and Mitchell MA. 2001. Comfortable ride: Concept 2000 provides climate control during poultry transport. Resource: Engineering & Technology for a Sustainable World, September, pp. 13-4.
[373] Wise DR and Jennings AR. 1972. Dyschondroplasia in domestic poultry. The Veterinary Record 91:285-6.
[374] Webster J. 1995. Animal Welfare: A Cool Eye Towards Eden (Cambridge, MA: Blackwell Science, p. 156).
[375] Cooper MD and Wrathall JHM. 2010. Assurance schemes as a tool to tackle genetic welfare problems in farm animals: broilers. Animal Welfare 19(Supplement): 51-6.
[376] Cobb. 2008. Products: overview. www.cobb-vantress.com/Products/Default.aspx. Accessed December 3, 2013.
[377] Ross. Ross Products. http://en.aviagen.com/ross/#. Accessed December 3, 2013.
[378] Rogers LJ. 1995. The Development of Brain and Behaviour in the Chicken (Wallingford, U.K.: CAB International, pp. 213-21).
[379] Griffin DR. 1992. Animal Minds (Chicago, IL: The University of Chicago Press, pp.162-4).
[380] Dawkins, MS. 2005. The science of suffering. In: McMillan FD (ed.), Mental Health and Well-Being in Animals (Ames, IA: Blackwell Publishing).

The Humane Society of the United States is the nation's largest animal protection organization—backed by 10 million Americans, or one of every 30. For more than a half-century, The HSUS has been fighting for the protection of all animals through advocacy, education, and hands-on programs. Celebrating animals and confronting cruelty. On the Web at humanesociety.org.