



An HSUS Report: A Comparison of the Welfare of Hens in Battery Cages and Alternative Systems

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Abstract

Housing systems for egg-laying hens range from small, pasture-based flocks to large, commercial-scale operations that intensively confine tens of thousands of hens indoors. The overwhelming majority of laying hens used for commercial egg production in the United States are confined in battery cages and provided 432.3 cm² (67 in²) of space per bird. Cages prevent hens from performing the bulk of their natural behavior, including nesting, perching, dustbathing, scratching, foraging, exercising, running, jumping, flying, stretching, wing-flapping, and freely walking. Cages also lead to severe disuse osteoporosis due to lack of exercise. Alternative, cage-free systems allow hens to move freely through their environment and to engage in most of the behavior thwarted by battery-cage confinement. Given their complexity, cage-free systems can be more challenging to manage and may require superior husbandry skills and knowledge. Laying hens must be genetically suited to the alternative housing system to realize its full welfare advantages. Regardless of how a battery-cage confinement system is managed, all caged hens are permanently denied the opportunity to express most of their basic behavior within their natural repertoire. The science is clear that this deprivation represents a serious inherent welfare disadvantage compared to any cage-free production system.

Cages and Alternative Systems

Three basic housing systems are used in commercial egg production in the United States: battery cages, barns, and free-range.

An estimated 95%¹ of the 280 million hens in the U.S. egg-laying flock² are confined in battery cages.³ Egg industry guidelines recommend 432.3 cm² (67 in²) of floor space per typical egg-laying hen,⁴ and the most commonly used cages hold 5-10 birds per cage.⁵ Cages are placed side by side, lined in rows, and stacked in tiers up to five levels high; tens of thousands of hens can be caged in a single building. Conventional battery cages provide a feed trough and water lines, but are otherwise barren environments. Scientists using preference testing techniques have demonstrated that hens generally prefer more space than is provided to them in a conventional battery cage.^{6,7,8,9,10}

Alternative laying hen housing systems, barns and free-range, vary widely both in design and management practices and requirements but, in contrast to battery cages, allow birds to move about freely. In barn systems, hens do not have outdoor access but are provided with nest boxes and often perches and loose substrate (litter or sand) for dustbathing, scratching, and foraging. Barns may be single- or multi-level structures. Single-level barns may be “deep-litter” systems, similar to the conditions in which broiler (meat-type) chickens are raised, or designed with perforated flooring, which allows manure to drop into a pit below. Multi-level barns (aviaries or

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percherries) utilize vertical space within the building and enable hens to move within multiple stories. Free-range systems, whether small, backyard flocks or large-scale production operations, provide both a protected indoor shelter or barn area and outdoor access.

Measures of Welfare

Welfare encompasses both the physical and psychological well-being of an animal. A housing system may affect the welfare of hens in a number of different ways. Scientists studying animal welfare generally agree that the best approach to assessing welfare is to integrate information across disciplines, using several different methodologies.^{11,12,13} As such, to determine an animal's welfare in a given housing system, indicators such as mortality rate, physiological measures (typically of stress indicators), disease and health status, behavior, and productivity must be examined together. Analyzing a sole indicator, such as productivity, can often be misleading if other indicators suggest a conflicting conclusion. A holistic approach to evaluating welfare, using all the available science, results in a more complete assessment.

Natural Behavior and Behavioral Needs

Domesticated animals largely retain the basic behavioral repertoire of their wild counterparts.^{14,15} Although selective breeding over thousands of years has altered animals in some ways through the process of domestication, natural selection has had a much stronger influence in shaping animal behavior over hundreds of thousands, if not millions, of years. Some behavior is so deeply engrained in the animals' genetic makeup that it will persist even in environments that no longer require that behavior for survival. Colloquially, this type of behavior is known as instinct, but ethologists (scientists who specialize in the study of animal behavior) describe it in terms of motivation and behavioral needs—strongly motivated behavior controlled largely by internal factors (such as changes in hormone levels) that are present no matter what type of external environment is provided.¹⁶

Artificial housing environments often prevent the expressions of certain natural behavior, including many that are behavioral needs. Behavior identified as important for the well-being of hens, includes nesting, perching and roosting, scratching and foraging, dustbathing, engaging in comfort behavior (such as wing-flapping and preening), exercising, and exploring.

Nesting

Nesting behavior is so important to the laying hen that it is often used as a prime example of a behavioral need.¹⁷ Under natural conditions, approximately 90 minutes before oviposition (egg laying), a hen locates a remote, private place in which she carefully scrapes out a shallow hollow in the ground and builds a nest. Very similar behavior can be seen in non-cage husbandry systems for hens.^{18,19} Nesting behavior is triggered internally with a sudden rise in progesterone against a background of fairly high estrogen levels. This hormonal fluctuation, associated with ovulation, then results in nesting behavior approximately 24 hours later.^{20,21} The internal, biological signals to perform nest-site selection and nesting behavior occur no matter what the external environment.²² Studies have shown that hens are highly motivated to gain access to a nest site when they are about to lay an egg.^{23,24} Caged hens prior to oviposition are restless, show stereotypic pacing and escape behavior, or perform “vacuum” nesting activity, the expression of the motions of building a nest in the absence of appropriate nesting materials. Decades of scientific evidence suggest that hens are frustrated and distressed, and that they suffer in battery cages because there is no outlet for nesting behavior.^{25,26,27,28,29,30,31}

Perching and Roosting

Barren with wire mesh flooring, conventional battery cages also prevent hens from perching and roosting. Perching is another natural behavior of the hen. When given the opportunity, hens normally roost high in the trees at night. The scientific literature suggests that the foot of a hen is “anatomically adapted to close around a perch”^{32,33}—that is, their feet evolved to clutch onto branches. Perch use is important for maintaining bone

volume and bone strength.^{34,35,36} Perches can also serve as refuges for hens to avoid interactions with more aggressive hens.³⁷

In a naturalistic setting, roosting behavior is thought to function in protecting chickens from predation at night, but evolutionary history continues to drive the hen's need to perform the behavior, even in the industrialized production environment. When perches are provided in cages, hens may spend 25-41% of day time on them,^{38,39,40} though this may be the birds' method of utilizing the extra space.⁴¹ Hens immediately begin to use perches when the lights go off at night, and, in one study, within 10 minutes, more than 90% of all hens were found on perches.⁴² When perch space is limited, hens will crowd together for roosting space at night.⁴³ In motivational analysis experiments, hens show behavior indicative of frustration when thwarted from accessing a perch.⁴⁴ They are also willing to push through an increasingly heavily weighted door for perch access.⁴⁵ Thus, many studies conclude that hens are highly motivated to a perch.^{46,47,48}

Scratching and Foraging

The wire floor of a battery cage also deprives hens of the opportunity to express normal foraging and scratching behavior. Hens are behaviorally adapted to engage in these activities, which would normally take place in loose, varied ground cover. The birds scratch the earth in search of food and as a means of exploring the environment, and studies have reported that domestic fowl spend more than 50% of their active time foraging.^{49,50} Battery-caged hens are fed a concentrated diet, yet, like other animals in captivity,⁵¹ their natural urge to forage remains strong, despite the presence of a complete diet fed *ad libitum*. Studies have shown that hens will choose to forage for feed on the ground in loose substrate rather than eat identical food freely available in a feeder.^{52,53} The lack of appropriate foraging substrate may lead to redirected pecking and to the development of abnormal feather-pecking behavior.⁵⁴

Dustbathing

The absence of loose litter in a battery-cage environment is also behaviorally restrictive as hens are prevented from performing normal dustbathing behavior. Dustbathing keeps chickens' feathers and skin in healthy condition. Given access to dry, friable substrate, such as dirt, wood shavings, or peat, hens would normally dustbathe approximately once every other day. During a dust-bath, the hen crouches, lies in, and rubs dust through her feathers before standing and shaking off the loose particles. The best experimental evidence suggests that the function of dustbathing is to balance lipid levels in the feathers.^{55,56,57} However, dustbathing is caused by a variety of factors, some of which are external⁵⁸ and others internal.^{59,60} Light and heat trigger dustbathing, as does the presence of a friable, dusty substrate, but even when deprived of these normal eliciting stimuli, hens in battery cages will still try to dustbathe on the wire floor. Peripheral factors, emanating from the feathers (including ectoparasites), seem to be unimportant since even featherless chickens will dustbathe.⁶¹ Although there has been a report of dustbathing deprivation leading to stress,⁶² others have suggested that dustbathing is not driven by a need, but is a pleasurable activity.⁶³ This does not lessen its importance, since good welfare is dependent on both an absence of suffering and a presence of pleasure.⁶⁴

Engaging in Comfort Behavior

Many studies have shown that comfort behavior important for body maintenance and care of feathers, such as stretching, wing-flapping, body-shaking, and preening, are reduced or adversely affected in some way by the battery-cage environment.^{65,66,67,68} The social spacing in a typical battery cage is restrictive to the point that hens may perceive their environment as being too small to engage in comfort behavior. Therefore, even if it is physically possible to perform these simple movements, they may not. Researchers comparing behavior in cages and cage-free systems concluded that an aviary was "a more comfortable environment for birds."⁶⁹

Exercising

Hens in cages are so intensively confined that they have no opportunity to exercise and are not exposed to the normal range of physical forces that structure their bones. The scientific literature provides ample evidence that restriction of normal movement patterns to the extent found in cages causes physical harm in the form of bone weakness. Dynamic loading is a process that occurs during normal movements and causes stresses and strains to bone and muscle that keep the skeletal system healthy. The lack of exercise in cages leads to bone fragility and impaired bone strength.^{70,71,72,73} While all hens selectively bred for egg production are prone to skeletal weakness due to osteoporosis (see below), caged hens are more prone to the disease due to lack of exercise. Several studies have compared the bone strength of caged hens to those in perchery and deep-litter systems. Findings conclude a very significant reduction in bone strength in the birds in cages.^{74,75,76} This problem is so severe that in one study, 24% of birds removed from their cages at the end of the laying period suffered from broken bones.⁷⁷

Preference testing has demonstrated that hens prefer more space than is typically allotted to them in a conventional battery cage and that when given the opportunity to choose between enclosures that differ in size, they will generally choose the larger enclosure.^{78,79,80,81,82} Preference tests have also demonstrated that space *per se* may not be as important as access to other resources, such as a littered or grass flooring and outdoor access.^{83,84,85} Additionally, smaller areas may temporarily be preferred for particular activities, such as nesting.⁸⁶

Exploring

Hens are naturally inquisitive, curious animals. Scientists have argued that exploratory behavior is important to animals on several grounds: Exploration satisfies the motivation to acquire information about the surrounding environment, creates agency and competency, and is also an end in itself.^{87,88,89} Some have further argued that situations that deny environmental challenge (because they are barren and devoid of natural stimuli) deprive animals of “the very core on which their physical existence is based, namely the ability to act.”⁹⁰ Exploratory behavior may be independent of goal-directed behavior (e.g., searching for a suitable nest site or foraging for food) as chickens continue to display exploratory behavior even when the functional consequences of this behavior (e.g., nest sites and nutritious food) is present.⁹¹ Exploratory behavior is likely a behavioral need.⁹²

Free-range systems offer benefits for exploration that no other system can provide. Only the day-to-day changes in an enriched outdoor environment offer novelty to the extent that chickens and other animals need in order to satisfy the natural drive to investigate, manipulate, and interact daily with a variety of interesting stimuli. Animals are biologically prepared to experience such a variable environment; the complexity of a dynamic environment is engaging, heightens interest, and adds to animals’ quality of life. The rich, diverse outdoor environment stimulates exploratory behavior and elicits pecking and scratching.⁹³ Enriched environments influence the physical, mental, and social well-being of animals and can improve animal health.⁹⁴

The converse is also true: Barren, restrictive environments are detrimental to the psychological well-being of an animal. When environments are predictable, monotonous, and unchanging, they do not offer the degree of stimulation or opportunity for choice that would be found in natural environments.⁹⁵ Scientists have suggested that environmental challenge is an integral part of animal well-being and that barren environments lacking challenge and stifling exploration engender apathy, frustration, and boredom.^{96,97} While single- and multi-level barn housing systems are not as engaging as free-range systems, they do provide more environmental enrichment and opportunity for stimulation than does a barren battery cage.

Conclusions on Behavior and Behavioral Needs

John Webster, Emeritus Professor of Animal Husbandry of the University of Bristol, Department of Clinical Veterinary Science, has stated that “the unenriched battery cage simply does not meet the physiological and behavioural requirements of the laying hen, which makes any quibbling about minimum requirements for floor space superfluous.”⁹⁸ Indeed, behavioral restriction is a severe problem in conventional battery cages. Without

the opportunity to engage in behavior that is important to the hen, quality of life is poor, and physical and psychological health is impaired. In a review of the scientific literature, the European Food Safety Authority's Scientific Panel on Animal Health and Welfare (AHAW), an independent advisory body that provides a science-based foundation for European policies and legislation, concluded: "Housing systems for hens differ in the possibilities for hens to show species specific behaviours such as foraging, dust-bathing, perching and building or selecting a suitable nest. ...Hens should be provided with sufficient space to allow the movements described above to be carried out by each bird taking into account the presence of other birds and the frequencies of exercise and other activities required by the birds to avoid significant frustration, or deprivation or injury."⁹⁹ Clearly, science supports what common sense dictates about the extreme confinement of hens in barren battery cages: Welfare is compromised to an unacceptable degree by preventing the expression of so many important behavioral activities.

Abnormal Behavior: Cannibalism and Feather-Pecking

Some abnormal behavior of birds may cause severe injury and even death, such as feather-pecking and its most severe form, cannibalism. There are a number of underlying genetic and production management causes, including crowding, barren environments, and lack of loose litter.^{100,101,102,103,104,105} Some hen strains are more likely to develop the behavior than others, particularly the medium-heavy brown hybrid birds.¹⁰⁶

Cannibalism is a learned behavior, passed on from one hen to another,¹⁰⁷ and has been reported in all types of housing systems.¹⁰⁸ Once an outbreak occurs, it is very difficult to control. The potential for the behavior to spread may be increased in large flocks,¹⁰⁹ as more birds are likely to learn the behavior or to become victims.¹¹⁰ Due to the restrictive nature of battery cages, hens are unable to access many other birds, which may make the behavior easier to manage,¹¹¹ although, feather-pecked hens in cages are unable to escape more aggressive cage-mates.

Within the egg industry, beak-trimming (also referred to as partial beak amputation) is commonly performed as a preventative measure as injurious pecking is a potential problem in commercial-scale cage and non-cage operations. However, the mutilation is a welfare issue in itself as it is painful, deprives the hen of important sensory information provided by the highly innervated beak tip,^{112,113} and is performed without anesthetics or analgesics.¹¹⁴ One systematic review, after beak-trim status and strain were accounted for, found no difference in rates of cannibalism¹¹⁵—that is, cannibalism rates were not determined to differ between beak-trimmed hens of the same strain raised in cage versus cage-free systems.

As cannibalism can result in high mortality, mitigating outbreaks is necessary for any production operation, particularly those with high stocking densities and/or non-beak-trim practices.¹¹⁶ Important steps can be taken to minimize risk of feather-pecking behavior, including providing sufficient space and access to resources such as properly nutritious feed, water, nest boxes, and perches; providing mash rather than pelleted feed; separating injured and low body weight individuals; installing visual barriers; avoiding lighting programs designed to bring about early onset of lay; and, importantly, providing an enriched environment with attractive foraging materials.^{117,118,119,120} Further, housing that allows potential victims to avoid aggressors may also aid in preventing injurious pecking.¹²¹ Ultimately, a potential solution to this particular problem is selective breeding for hen strains showing little cannibalistic behavior.^{122,123,124,125,126}

In sum, the complexities of preventing and addressing this abnormal behavior are many:

[N]eural and behavioral evidence suggests that beak trimming reduces welfare through causing both acute and chronic pain. The problem is that beak trimming is carried out for the very good reason of preventing or controlling feather pecking and cannibalism, which can themselves cause great suffering. Faced with this dilemma, what are producers to do? If they do not trim beaks, then feather pecking and cannibalism may cause enormous suffering. If they do trim beaks by conventional methods, the birds will suffer from acute and chronic pain...It is known that feather pecking has hereditary characteristics...and that its incidence may have been increased by unintentional genetic selection...It

therefore seems likely that the long-term solution to this problem will be a genetic one...Chopping off parts of young animals in order to prevent future welfare problems is a very crude solution.¹²⁷

Health, Disease, and Injury

General Disease Considerations[‡]

Laying hens can suffer from infectious diseases, parasites, and production-related metabolic and reproductive diseases both in cages and cage-free systems; however, the housing environment can affect the type and extent of disease risks. Systematic studies of disease incidence are uncommon,¹²⁸ though, so accurately gauging the true extent of diseases on cage and cage-free farms in the United States is challenging.

Access to the outdoors can influence the type of disease risks to which hens are exposed. For example, outdoor flocks may be exposed to wild birds, insects, and other potential infectious agents,¹²⁹ and may come into contact with bacteria and intestinal parasites, such as certain nematodes and cestodes (worms) and coccidia.^{130,131,132,133} Pullorum disease, a type of *Salmonella* infection, is currently rare in commercially raised chickens, but may occur in backyard flocks¹³⁴ if appropriate precautions are not taken.¹³⁵ It was once widely believed that free-range chickens were more likely to come into contact with the bacterium *Campylobacter jejuni*,¹³⁶ but a 2008 research report suggests that this is not the case.¹³⁷ Concurrently, other disease risks are minimized by factors associated with the outdoor, free-range environment: Natural sunlight kills many pathogens and virus particles, and the lower stocking densities and access to fresh air typical of free-range flocks lower infection and transmission rates.¹³⁸ Disease risks can be heightened by overcrowded and unsanitary outdoor environments, necessitating responsible management, including rotation of fields or paddocks.

A separate but related disease risk factor is the degree to which hens are crowded. Confinement rearing and high-density flocks increase exposure to protozoal infections with short, direct life cycles, such as coccidiosis and cryptosporidiosis.¹³⁹ Where stocking density is high, the environmental pathogen load may be correspondingly heavy, and bird-to-bird contact will be more frequent. Such overcrowding has been implicated as a factor in the emergence of highly pathogenic strains of avian influenza.¹⁴⁰

The risk of enteric disease is heightened by contact with droppings, which can occur in deep-litter and free-range systems, not only for laying hens, but for all birds reared on litter, including breeding birds used to produce hatching eggs for commercial egg producers, and is exacerbated by high stocking density as well as wet and cool conditions.¹⁴¹ Therefore, in a barn system, litter that stops working, leaking drinkers, and an inadequate ventilation system (to remove water vapor) may all increase disease risk.^{142,143} Similarly, inadequate rotation of fields or paddocks in free-range systems may elevate disease incidence by allowing build-up of disease-producing organisms in the soil. Risk of disease can be reduced in barn housing by removing some of the droppings (e.g., via a belt in aviary and perchery systems, for example) or by preventing birds from accessing heavily soiled areas (e.g., by placing drinkers on a raised, slatted platform above a manure pit).

Free-range conditions greatly reduce the risk of respiratory disease in hens. In indoor systems, the risk of infection may be increased by high levels of ammonia and fecal dust, which can damage the respiratory tract.¹⁴⁴

Disease risk in cage-free systems can be reduced by a variety of means. In barn housing, providing good ventilation,¹⁴⁵ maintaining litter in friable condition,¹⁴⁶ using dewormers,¹⁴⁷ stocking hardy laying hen strains resistant to intestinal parasites¹⁴⁸ and introducing only parasite-free, healthy pullets,¹⁴⁹ feeding diets that improve resistance,¹⁵⁰ reducing flock size and stocking density,^{151,152} and practicing responsible biosecurity measures that reduce the likelihood of pathogen spread all minimize risk of disease. For free-range systems, in addition to

[‡] In-depth analysis of every disease that may affect cage and cage-free systems is not possible in this report, given the vast scope of such an evaluation, which is made more challenging given the limited disease reporting from individual farms. As such, only general disease considerations and the most commonly cited disease issues discussed in the debate over laying hen welfare are included herein.

these steps, disease risk can also be reduced by utilizing pasture rotation to regenerate soil, regularly mowing or grazing to keep short vegetation on pasture, using only land with good drainage, removing heavily contaminated soil around the house before introducing a new flock, and installing fencing and bird mesh to exclude wild birds and other animals.^{153,154,155}

Parasites

Coccidia, intestinal parasites that are shed in fecal material, may affect all types of poultry in all types of housing systems,¹⁵⁶ though caged hens are generally protected by separation from their fecal material, which breaks the parasite's lifecycle. For birds raised in cage-free systems, coccidiosis is not normally problematic when, as pullets, they are reared on the floor and given a low level of coccidiostat to develop premunity.¹⁵⁷

To reduce the incidence of coccidiosis, as well as other diseases, flocks should be stocked with healthy pullets. As with other types of poultry, coccidiosis can be controlled in laying hens by feeding them anticoccidial medication. Since personnel traffic between pens, houses, and farms can spread coccidiosis,¹⁵⁸ careful management, particularly with sanitation or biosecurity precautions such as limiting movement between flocks, will also help prevent its spread. Small flocks with low stocking density typically develop immunity through low level exposure.¹⁵⁹

Another parasitic disease of the intestinal tract, histomoniasis, also known as Blackhead, is a re-emerging disease in alternative housing systems for laying hens in Europe.¹⁶⁰ Widespread outbreaks are also causing severe clinical disease in broiler chicken breeders and laying hen pullets (who are reared on littered floors) used for both battery cage and cage-free production systems in the United States. The problem has been compounded by bans on nitroimidazoles used to treat the disease in both the United States¹⁶¹ and Europe¹⁶² due to human health concerns. Histomoniasis is indeed a cause for concern, as mortality can be very high in infected chicken flocks,¹⁶³ but is not limited to affecting hens in cage-free production systems.

Red mites, also called chicken mites, are another external parasite of concern for laying hens, particularly those reared in alternative systems^{164,165} in European countries where the legal use of drug compounds that have been used in the past have become increasingly restricted.¹⁶⁶ New treatments, such as the acaricidal drug phoxim, are proving to be highly effective¹⁶⁷ without exceeding maximum residue levels set by the Council of Europe.¹⁶⁸ Further, several effective natural products are currently available or under development.^{169,170} As well, in the United States, approved acaricidal products have always been permitted for use. Although red mites are less common in cage-layer operations, they are more problematic on industrial broiler chicken breeder facilities.¹⁷¹ Nevertheless, according to the management guide for Hy-Line® strain hens, mites, in general, are a cause of increasing concern for both battery cage and free-range laying hens.¹⁷²

Respiratory Disease

Dust and micro-organisms may be found at higher levels in alternative systems when birds are housed indoors on loose litter. High levels of dust may lead to respiratory problems, but these levels are seldom reached in commercial egg production systems.¹⁷³ Cage-free egg producers can use clay pellets for bedding and sprinkler systems to reduce dust levels.¹⁷⁴ Ammonia levels in alternative systems can be higher than in conventional cages, which can be detrimental to hen respiratory and eye health, but good manure management, including frequent removal and manure drying, can reduce ammonia to safe levels.^{175,176}

Fatty Liver Hemorrhagic Syndrome (FLHS)

A major cause of mortality in commercial flocks,¹⁷⁷ FLHS is characterized by excessive fat deposits in the hen's liver and abdomen. The liver softens and becomes more easily damaged, and, if the fat oxidizes, blood vessels in the liver may rupture, resulting in massive bleeding and death.^{178,179} Caged laying hens on high energy diets are the most frequently affected by this disease,^{180,181} and multiple sources suggest that restriction of movement and lack of exercise, inherent in battery-cage systems, are factors that predispose the birds to FLHS.^{182,183,184,185}

Foot Disorders

The type of floor surface in any housing system will positively or negatively affect the foot health of hens. Two common foot disorders of laying hens are toe pad hyperkeratosis and bumblefoot, which is thought to be more painful and of greater welfare significance.¹⁸⁶

Toe pad hyperkeratosis, a thickening of skin on the feet of hens, is thought to be caused by pressure on the claw fold due to the sloping wire floor of a cage;¹⁸⁷ the disorder has been demonstrated to be worse in cages where hens stand on wire flooring than in systems that allow birds to perch.^{188,189} Severe hyperkeratosis may be accompanied by deep epithelial lesions (open sores) and/or swelling of the foot pads.¹⁹⁰

Bumblefoot is a bulbous swelling of the footpad caused by a localized infection.¹⁹¹ As the disorder is related to perch use, incidence of bumblefoot is typically greater in cage-free systems compared to conventional cages that are barren,^{192,193} yet while the precise cause is not known, some hen breeds are more susceptible than others, and the condition is associated with poor hygiene and poor perch design,^{194,195} both issues of management practice rather than housing system. According to AHAW, in many studies, the use of plastic perches or the commonly used soft wooden perches measuring 25 mm (0.98 in) in width is thought to have been the cause of poor foot health as manure and moisture are able to accumulate on the structure's top where the birds' feet rest.¹⁹⁶ Incidence of bumblefoot can be reduced by providing hens with hardwood perches that are 38 mm (1.49 in) in diameter with a flattened top^{197,198} and by limiting walking exposure to mud and manure.¹⁹⁹

Keel Bone Disorders

Deformities of the keel bone are thought to occur when hens roost in places other than purpose-built perches, such as on the edge of feeders, water lines, or boxes for containing loose litter. One study reported that 25% of aviary-housed hens had keel bone deformities,²⁰⁰ though another reported that the level of keel bone deformities can also be high (16.7%) in caged laying hens.²⁰¹ There are strain differences in the propensity to develop keel bone deviations.²⁰² Occasionally, deviation of the keel bone can develop into bursitis,²⁰³ inflammation between the bone and muscle. However, keel bone deformities can be reduced—or eliminated completely, as was the case in one study—by selective breeding for improved skeletal strength²⁰⁴ and by improved design and layout of barn housing fixtures, such as perches.^{205,206}

Osteoporosis

Osteoporosis due to lack of movement is a severe problem in caged laying hens. It is well-documented in the scientific literature that bone strength is improved in alternative housing systems compared to conventional battery cages.^{207,208,209,210,211,212} Studies have demonstrated that restriction of movement, especially the thwarting of normal behavior such as stepping and wing-flapping, is the primary cause of bone fragility for laying hens^{213,214} and that exercise improves bone strength.²¹⁵ Osteoporosis can lead to bone fractures and cage layer fatigue.²¹⁶

Cage Layer Fatigue

Cage layer fatigue was first identified when laying hen flocks were moved into cages during the advent of intensive farming in the 1950s and continues to be a “major issue.” The disease is “virtually unheard of” in birds who are not raised in cages.²¹⁷ Cage layer fatigue is related to osteoporosis in that it is a consequence of skeletal depletion due to high, sustained egg output; bone is the metabolic reservoir for calcium used in egg shell formation.²¹⁸ The skeletal system of hens suffering from cage layer fatigue can become so weak that hens become paralyzed. Affected birds may have fractured thoracic vertebrae associated with compression and degeneration of the spinal cord.²¹⁹ However, if they are removed from their cages and allowed to walk normally on the floor (that is, if they are allowed to exercise) and are given feed and water, some may recover spontaneously.^{220,221,222} Unattended birds will die from dehydration and starvation in their cages.^{223,224}

Bone Fractures

One of the most serious threats to hen welfare in both cage and cage-free systems is the prevalence of bone fractures. Poor skeletal bone mass of laying hens may have occurred as a consequence of selective breeding to maximize egg production,²²⁵ as calcium needed for shell formation is diverted from bone.²²⁶ Modern laying hens produce more than 250 eggs per year,²²⁷ compared to 100 eggs per hen per year a century ago.²²⁸ The calcium requirement for today's extremely high rate of egg production is immense, and moving calcium from bone to egg shell leaves the hen prone to osteoporosis. Although nutrition plays a role in reducing the severity of osteoporosis, changes in genetics and housing are more important.²²⁹ AHAW noted that the prevalence of bone fractures that hens sustain during the laying period appears to be increasing.²³⁰

Osteoporosis and the accompanying bone weakness are worse in caged hens, due to lack of exercise, while hens in cage-free systems experience bone fractures at a higher rate than hens in cages, most likely because they have more opportunities to move. Indeed, it has been suggested that birds in cage-free systems, compared with those in barren cages, face greater structural complexity that can increase the risk of fractures due to collisions and falls,²³¹ during unsteady landings as hens fly down from one level to another in aviary systems or as they fly down from perches, for example. However, even birds in battery cages and single-level cage-free systems, where the risk of crash landings would be expected to be low, are prone to fractures.^{232,233} Hens with fractures must endure the pain associated with their injuries throughout the process of healing, as fractures generally go unnoticed by producers.

Studies on fractures sustained by laying hens have produced a wide range of findings. Some estimates have found that a high number of hens in free-range and other cage-free systems suffer from bone fractures, with prevalence varying between 50-78% of birds having old breaks by the time they have reached the end of the laying period,^{234,235} while at least one study reported no bone fractures at all for cage-free hens.²³⁶ Earlier studies from the 1990s show a lower incidence,²³⁷ with 2-42% of free-range and 11-30% of perchery hens having old bone breaks.²³⁸ However, although the incidence of old breaks obtained during the laying period are higher for uncaged hens, caged hens are also prone to fractures. Recent studies have reported 11% and 26% incidences of old breaks in commercial strain caged hens.^{239,240} Studies from the 1990s put the incidence of old breaks for caged hens between 0-15%.^{241,242,243} Further, one study reported that the incidence of pathologic breaks during the laying period can be worse in caged hens; the study tested the same genetic strains in both cage and aviary systems and found that 31.9% of caged hens who died during the first trial of the study had recently broken bones, compared to only 4.6% of aviary hens. The numbers were lower in the second trial, when a different genetic strain was used: 12.8% of caged hens died with recent breaks, while only 1.3% of aviary hens had recent breaks.²⁴⁴ Another study also found that bone fractures were the main cause of mortality in caged hens.²⁴⁵ Because the problem is worsening, while at the same time aviary housing has become more popular, estimates that are not direct comparisons between cage and cage-free systems that account for strain differences may be misleading, especially if old figures for caged hens are compared to new figures for hens in cage-free systems.

At the end of the egg-laying cycle, when productivity wanes and the entire flock is to be culled and replaced with new pullets, the "spent" hens are removed in a process termed "depopulation." Catching crews gather the birds and either crate them for transport to a slaughter plant or, as is increasingly the case, the hens are placed into a gas-filled container for killing on-site. Bone breaks occur with alarming frequency during depopulation of caged hens for two primary reasons: 1) their bones are especially weak due to lack of exercise, and 2) cages are poorly designed for bird removal. A 2005 study reported that nearly 25% of caged hens suffered from fresh bone breaks during depopulation, while just slightly more than 10% of hens from barn and free-range housing systems suffered bone breaks as they were caught during depopulation.²⁴⁶ Early studies from 1989 and 1990 report similar to slightly lower rates of newly broken bones in hens removed from cages at the end of the laying period, with estimates ranging between 16-24%.^{247,248} If hens are transported, unloaded, and shackled for slaughter, the proportion of birds with broken bones may increase to approximately 30%.^{249,250} When housing systems were compared, less than half that amount—14%—of free-range hens had broken bones after shackling for slaughter.²⁵¹

Different hen strains vary in their susceptibility to weak bones.^{252,253} Skeletal fragility is a production disease and is not found in the unselected lines²⁵⁴ or heritage breeds²⁵⁵ raised primarily on small farms. Researchers at the Roslin Institute have demonstrated that bone strength is moderately to strongly heritable,^{256,257} therefore, the problem of bone fractures could be solved by selectively breeding for enhanced bone strength, rather than productivity above all other traits.

Other Injuries

Injuries to hens can occur in any system that is inadequately designed or in need of repair. Poor cage design and loose wires can trap hens and puncture and tear skin. Although newer cage designs reduce trapping incidence, cages in disrepair are still dangerous. Caged laying hens are more prone to overgrown claws due to lack of abrasive substrates that would naturally keep the claws short. Overgrown claws can become caught in cage wires and may tear and bleed. Abrasive strips made from a variety of different materials including ceramic plate, tungsten, and embossed metal can be added to cages to reduce claw growth.²⁵⁸

In cage-free systems, frightened birds may panic and rush to one side of an open barn. If they pile on top of one another, suffocation of the birds beneath can occur,²⁵⁹ though this is a relatively infrequent event,²⁶⁰ and precautions such as subdivision of the flock can prevent this event altogether.

Conclusions on Health, Disease, and Injury

Although disease risks and bone fracture incidence are sometimes used to condemn cage-free production systems, when barn-raised hens are provided well-designed fixtures on perforated flooring or are otherwise separated from their manure in alternative systems, disease risks are comparable to hens in cages. Cage-free, deep-litter systems have disease risks similar to other types of poultry production methods that raise birds indoors on litter, such as broiler chickens, turkeys, and breeding flocks. Hens with outdoor access may be exposed to a greater variety of infectious agents, but low stocking density, fresh air, and sunlight are advantages for disease control that indoor housing systems do not provide. In all cases, good management is necessary to reduce potential disease risks.

As lack of exercise contributes to bone weakness in caged laying hens, even if genetic selection strategies to improve bone strength were implemented and bone strength was improved in the commercial laying hen population, caged hens could still suffer from bone weakness due to disuse osteoporosis. Animals are designed to move, are biologically prepared for regular movement, and will suffer physical consequences if they are not given the freedom to exercise. Hens should be biologically sound and healthy, and able to move freely and without risk of injury, as they were before commercial breeding practices pushed them toward their biological limit. The solution to this problem should be pursued by science and industry in conjunction with the move toward cage-free systems.

Mortality

Although mortality in cage-free systems is at times claimed to be higher than in caged systems, research has found that mortality during the laying period is generally low and similar between all housing systems.²⁶¹ Studies are beginning to reveal that differences in mortality between systems are not due to the housing system *per se*, but to management decisions, such as choice of hen strain and whether or not to beak-trim the birds. Indeed, husbandry practices and production methods are critical to hen welfare. In outdoor systems that do not protect hens from predators, for example, mortality can be excessive,²⁶² but this is not typical, as it would be commercially unwise as well as inhumane to rear chickens outdoors without protection from predation. Similarly, mortality can be high in cage-free flocks with intact beaks²⁶³ if responsible management steps to minimize risk of injurious pecking are not taken, as outlined in detail above. In a systematic review of 14 different studies, in which beak-trimming status and hen strain were accounted for, mortality rate did not differ between cages and aviaries. Mortality can be reduced in cage-free systems by choosing a suitable hen strain,²⁶⁴

taking necessary steps to prevent feather-pecking and cannibalism, and by protecting free-range flocks from predators.²⁶⁵

Stress

Several physiological correlates of stress can be measured and used as indicators of animal welfare. Corticosterone is a hormone in birds that increases in response to stressful situations, such as during handling for shackling at slaughter,²⁶⁶ and can be isolated and measured from blood or fecal samples. Another common method for measuring stress levels is to examine the ratio of heterophils to lymphocytes (two types of white blood cells involved in the avian immune response) in a blood sample. Heart rate may also be used as an indicator of stress.

A comprehensive analysis of the welfare of hens kept in various housing systems was undertaken by the LayWel research project, funded by the European Commission and several member countries of the European Union. A collaborative effort among working groups in seven different European countries that examined data collected from 230 different laying hen flocks,²⁶⁷ the LayWel project evaluated 16 independent experiments to study stress physiology. The researchers found that measures were highly inconsistent; depending on the physiological parameter measured, welfare assessment ran the full spectrum—from appearing to improve, compare to, or decrease in cages relative to alternative systems.²⁶⁸ These findings echo previous reviews.²⁶⁹

Given their results, the LayWel project team emphasized that physiological measurements of stress must be interpreted with caution. Using the results of one simple study of corticosterone or heterophil:lymphocyte ratio alone to draw conclusions about welfare can be misleading, as many factors can affect the stress response. For hens, these factors include the genetic makeup of the specific strain tested, the age of the hens, the episodic and irregular nature of corticosterone release, and the specifics of the stressor.^{270,271} Further, in some cases, corticosteroid measurements simply fail to accurately reflect stressful conditions. For example, while decreasing space allowance in cages consistently reduces productivity and increases mortality, there is no clear parallel affect on blood corticosterone levels.²⁷²

The LayWel project did find strong interactions between the physiological responses measured during the laying period and the rearing conditions of the hens. Thus, the environment during early development is important for adaptation of the hens to their future housing system and, consequently, to their welfare. Generally, stress is reduced when hens are reared in the same type of system they will be placed in during the laying period.²⁷³

Productivity

Poor productivity can be used as an indicator of poor animal welfare, as growth and reproduction of animals can be reduced by stress or impaired health. Coping with stressful situations requires reallocation of bodily resources toward maintenance functions, diverting them from productive performance.²⁷⁴ However, the converse is not necessarily true. Nevertheless, productivity records are a ready source of information for egg producers. When morbidity, mortality, and stress levels are high in a group, resulting in a clear drop in productivity, this may be used as an indicator that welfare is compromised.²⁷⁵ However, this measure of welfare must be interpreted with caution: The connection between welfare and productivity is tenuous and unreliable; productivity is often measured in economic returns for whole flocks, whereby individual birds experiencing poor welfare are not assessed; and comparisons between systems can be misleading.^{276,277,278} Indeed, as hens are specifically bred for high rates of lay, their productivity will not necessarily fall when conditions are sub-optimal,²⁷⁹ and acute, transitory physical or mental suffering will not necessarily affect productivity.²⁸⁰ Further, high productivity is an underlying trigger for most metabolic disorders.²⁸¹

While productivity in cage-free systems can be as high as battery-cage systems,^{282,283} feed conversion in cage systems is generally more efficient. That is, cage-free hens, who, unlike caged birds, are able to exercise, typically consume slightly more feed and therefore may have less efficient feed conversion ratios.^{284,285,286} However, lower productivity in cage-free systems does not indicate reduced welfare. Differences in productivity

and feed-conversion efficacy are due to a number of factors, including hen activity levels in cage-free systems (i.e., active hens consume more feed), feed wastage in alternative systems, greater temperature fluctuations experienced by free-range hens, and the fact that eggs that are lost (broken or eaten by hens) are not accounted for in productivity records for alternative systems.^{287,288,289} The underlying causes of reduced productivity in cage-free systems are not due to general differences in stress levels or health status of the birds.

Conclusion

The animal welfare community seeks to raise the bar for the care and treatment of egg-laying hens, but there is an inherent limit on how high that bar can be set in a battery-cage environment. Indeed, it is impossible to provide for the behavioral well-being of a hen confined in a conventional battery cage, as she cannot lay her egg in a nest, perch, forage, dustbathe, scratch, freely stretch, engage in normal social behavior, explore her environment, hide, exercise, fly, jump, flap her wings, or even freely walk. Although all current commercial systems have welfare challenges, only cage-free systems provide for the behavioral freedom of the hen and have the potential to provide her with good physical well-being as well.

Due to the difficulties in weighing the many factors involved in assessing overall animal welfare, some scientific reviews have concluded that there are pros and cons to each housing system. For example, in its opinion on the “Welfare Aspects of Various Systems of Keeping Laying Hens,” the Scientific Panel on Animal Health and Welfare identified the most severe threats to bird welfare in different production systems. For cages, these are 1) low bone strength and fractures sustained during depopulation, and 2) the inability to perform high priority behavior. For cage-free systems, the panel identified 1) bone fractures sustained during lay, 2) cannibalism, and 3) parasitic disease.²⁹⁰ However, in a clean, indoor, non-cage system with beak-trimmed birds, the only severe threat to welfare that remains is bone fractures sustained during lay.²⁹¹ Although this is indeed a serious problem, selective breeding is likely to make significant improvements in future hen strains.^{292,293} The welfare potential of a given housing system is increasingly being seen as a more meaningful way of characterizing the various systems. The potential to solve welfare problems exists for cage-free systems, but behavioral restriction is impossible to address in a cage, as explained by poultry scientist Michael Appleby, member of the Farm Animal Welfare Council, an independent advisory body established by the U.K. government:

I find battery production to be one of the most inhumane practices in factory farming and have argued strongly for reform in the egg industry, both as an animal science professor and humane advocate, for many years.

Battery cages present inherent animal welfare problems, most notably by their small size and barren conditions. Hens are unable to engage in many of their natural behaviors and endure high levels of stress and frustration.

Cage-free egg production, while not perfect, does not entail such inherent animal welfare disadvantages and is a very good step in the right direction for the egg industry.²⁹⁴

It cannot be denied that there are real welfare risks associated with cage-free environments if management is poor. Market forces may drive producers to overcrowd birds,²⁹⁵ undermining some of the potential welfare improvements in alternative systems. However, where managers are committed to animal well-being, most of the welfare issues can be, and are being, worked out to realize the greater welfare potential of non-cage systems. For example, advances in disease control²⁹⁶ and genetic selection for reduced parasitism²⁹⁷ and cannibalism^{298,299,300} will undoubtedly improve the welfare of cage-free flocks. Further, information is available to assist cage-free producers in managing their flocks by a number of entities, including the National Sustainable Agriculture Information Service³⁰¹ and the LayWel project.³⁰² Although hen well-being in cage-free systems is subject to how well the system is managed, even a well-managed battery-cage system cannot provide good welfare as caged hens are so severely behaviorally restricted.

The best welfare for hens used for egg production is attained when they are raised in small groups with freedom of movement in complex environments with safe outdoor access.³⁰³ Indeed, small, well-managed flocks with

low stocking density experience reduced risk of disease transmission, low probability of cannibalism occurrence (thereby minimizing or eliminating beak-trimming procedures), a more natural group size, and more individual attention from caretakers. Using hardy, heritage breeds or sound crosses would further reduce the incidence of health problems, including weak bones and subsequent high fracture rates. In any case, management must be good to ensure that welfare potential of these systems is maximized.

There is a strong argument, firmly based on scientific grounds, that cages are not and can not be appropriate environments for laying hens. According to the LayWel project's authoritative and comprehensive review of all of the current science:

Conventional cages do not allow hens to fulfil behaviour priorities, preferences and needs for nesting, perching, foraging and dustbathing in particular. The severe spatial restriction also leads to disuse osteoporosis. We believe these disadvantages outweigh the advantages of reduced parasitism, good hygiene and simpler management. The advantages can be matched by other systems that also enable a much fuller expression of normal behaviour. A reason for this decision is the fact that every individual hen is affected for the duration of the laying period by behavioural restriction. Most other advantages and disadvantages are much less certain and seldom affect all individuals to a similar degree.³⁰⁴

The LayWel research team determined: "With the exception of conventional cages, we conclude that all systems have the potential to provide satisfactory welfare for laying hens."³⁰⁵

Many other scientists agree that welfare is generally compromised more in cages than it is in well-run alternative systems and that the differences between systems amount to a clear welfare advantage for hens who are not confined to cages.^{306,307,308} In 2008, after a 2.5-year examination, the Pew Commission on Industrial Farm Animal Production, a project of The Pew Charitable Trusts and Johns Hopkins University Bloomberg School of Public Health, released a report based on technical information provided by leading academics. The report stated that the most intensive confinement systems used in animal agriculture, including battery cages for laying hens, constitute "inhumane treatment," and, among the final recommendations put forth by the 15 Commissioners was a complete phase out of battery cages.³⁰⁹

Yet, while science is indeed important, its usefulness in the debate about animal welfare has limits. Animal welfare judgments must also be based on ethical considerations and, in fact, are inextricably connected to them.^{310,311} The extent to which it is acceptable to use an animal is an ethical decision; science can provide factual information to inform the debate but cannot answer questions about morality.³¹² Further, while science has provided abundant factual information in many areas that affect animal welfare, other areas remain out of reach. The precise subjective states animals experience are still largely unknown to science. Until scientists can fully understand animals' minds, common sense, in combination with scientific facts, must be used to evaluate the effects an impoverished environment, such as a barren battery cage, might have on the psychological well-being of a confined animal. Where the science is incomplete, we must rely on common sense, good judgment, and a solid foundation of ethics, and provide the best possible environment for animals, erring on the side of the animals' perceived or actual best interest.

University Distinguished Professor of Animal Sciences, Biomedical Sciences, and Philosophy, Bernard E. Rollin, simply yet eloquently stated about laying hens: "Research has confirmed what common sense already knew—animals built to move must move."³¹³

Egg producers cannot be held entirely accountable for the welfare problems of laying hens; economics have driven them to continually seek methods for minimizing costs. Competition between producers has led to increases in the number of birds per house and per cage, and attempts to reduce labor requirements.³¹⁴ The decision to move to intensive production allowed producers to take advantage of economies of scale, but the animals have paid the added price. In the end, both science and ethics require that academics, consumers, retailers, advocacy groups, and industry work together to improve the welfare of egg-laying hens. Encouraging a move away from battery cage confinement systems works toward that end.

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