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Editor's Note:

Broiler Stocking Density and Welfare

In the past three years animal welfare issues have had a major impact on animal agriculture. The broiler industry has not been exempt from this challenge. The most proactive broiler companies have adopted the National Chicken Council (NCC) guidelines or have developed their own. In addition, some of them are taking serious steps toward changing or adjusting management practices that are considered controversial from the standpoint of animal welfare. One of the issues under heated debate at the present time is stocking density. Stocking density has major economic implications for the broiler industry as higher profits can be obtained when more animals are housed under one roof. However, as profits increase, the welfare of the animals may start to decline.

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Clearly we are facing an issue in which profit and welfare do not, necessarily, go in the same direction. Furthermore, the effects of density are multidimensional, because it may affect the health and welfare of the birds in many different ways.

On this issue we take a close look at the effects of broiler density on health and welfare. In these articles authors highlight the best management practices that may permit maintaining a reasonable stocking density while minimizing the negative impact on the welfare of the animals.

We hope you will find this issue informative, interesting, and valuable.

Inma Estevez
Editor

"Clearly we are facing an issue in which profit and welfare do not, necessarily, go in the same direction."

Stocking Density, Litter Quality and Poultry Welfare

by Bud Malone

Farm profitability can be negatively impacted by animal welfare issues. One of the more controversial animal welfare issues is the proposed guidelines to reduce stocking density. In a recent 2.7 million bird stocking density study in the United Kingdom, Dawkins, et al. (2004) found environmental conditions had more direct impact on broiler welfare than stocking density itself. High litter moisture and ammonia were identified as the welfare issues having the greatest negative influence on bird health, carcass defects, and the production of corticosteroid, a "stress" hormone. Although genetics, diet, and vaccination programs are beyond a poultry grower's control, the following management opportunities can help mitigate the negative consequences associated with high stocking densities, improve litter and air quality, and increase profitability and poultry welfare.

Litter Quality and Density

Litter quality tends to deteriorate (wetness and caking) quickly at high stocking density and consequently affects broiler performance and carcass quality. These adverse litter conditions, particularly during early growth, are a leading cause of foot pad lesions and other carcass defects. Malone and Martin (1997) found broilers reared at 0.70 ft^2 per bird had twice the incidence of foot pad lesions by 21 days of age compared to densities from 0.77 to 1.13. Even under typical placement densities birds can be subjected to stress from excessive densities in a house. Ways to minimize the impact of these stresses include timely movement of birds from the brood to growout chambers, and maintaining uniform temperature and light intensity throughout the house. Migration fences are an important management tool to balance bird density in both tunnel and conventional ventilated housing. In a study to determine the amount of cake produced in conventional houses, Malone (unpublished) found 25 of the 30 tons of cake removed during a summer flock in one house was confined to one end of the building. The birds had migrated toward the direction of air flow resulting in wall-to-wall massive caking under these high stocking densities. Timely installation of migration fences (preferably every 100 feet) will prevent the detrimental effects of high bird density due to migration in response

to differences in temperature, light intensity, and wind direction within houses. Even with timely installation of migration fences, uneven density will occur if the ventilation system is not properly designed and/or operated. Cull birds utilize precious floor, feeder, and drinker space; increase the potential for disease transmission; and should be removed promptly.

Impact of Wet Litter

Dry, dusty litter may contribute to increased chick dehydration, respiratory disease, and condemnations. However, wet litter is generally recognized as having a much greater negative impact on performance, carcass quality, health, animal welfare, and overall profitability. Ideally, litter should be managed to have approximately 25 percent moisture. Management of the drinker and ventilation systems is critical in maintaining proper litter conditions. With the advent of nipple drinkers, tunnel ventilation, evaporative cooling pads and electronic controllers, growers now have much better control of litter and air quality and can negate some of the issues associated with high stocking densities and wet litter. However, failure to properly manage and maintain these systems can negatively impact both the house environment and profitability. An example is timely replacement of worn nipple drinkers. After 5 years nipples should be evaluated for wear. Following replacement of worn nipples, reductions in caked litter volumes of 50 to 90 percent have been reported. Other management opportunities include regular pressure adjustment, proper line height, repairing leaking lines and pressure regulators, and routine flushing and line sanitation.

Of all house systems and management practices, proper ventilation is the primary means available to growers to maintain good litter and air quality. For each pound of weight birds generate 5 BTU and 0.01 pounds of moisture per hour. For a house of 25,000 broilers with 5-pound birds, this is 625,000 BTU of heat and 150 gallons of water per hour the ventilation system must remove! House sweating and condensation in cold weather can also create wet litter. Donald, et al. (2004) suggest growers maintain <70 percent relative humidity, operate 0.10 static pressure with 1 to 1.5 inch inlet opening, seal cracks and air leaks, consider using mixing fans, check for areas of inadequate ceiling insulation, use caution when using only off chamber fans during brooding, and use heat with large birds if needed to maintain air and litter quality. With tunnel ventilation and evaporative cooling pads, litter conditions during hot weather have greatly improved. However, setting evaporative cooling pads to operate at too low a temperature may lead to wet litter at the tunnel curtains (Czarick and Fairchild, 2003).

> *"...proper ventilation is the primary means available to growers to maintain good litter and air quality."*

Other farm-related factors that contribute to wet litter conditions include wet or poor bedding quality, inadequate litter depth, deteriorated house pads, and poor site drainage. Litter moisture control starts with building houses on an elevated pad, and maintaining good in-house pad depths and drainage throughout the life of the facility. Over time drainage around houses deteriorates, causing ponding and water seepage into the house. During wet weather or intense rain events, this can represent a major source of wet litter in houses having poor drainage.

The Relevance of Litter Depth

Managing litter depth is critical in a built-up litter program. This starts with placing an adequate initial depth of 3 inches or more. It has been the author's experience at depths less than this amount, caking is often excessive and leads to greater bedding replacement costs over time. Another source of wet litter is high moisture bedding materials. Mill-run sawdust that has been stored outside often exceeds 45 percent moisture. This can represent up to 6 to 7 tons of water that must be removed from the house when used as the bedding source. If one starts with a wet bedding material, moisture from only the top two inches of the litter surface will be reduced by the ventilation system during a flock. Undisturbed, it may require several flocks to dry the lower litter profile and with very deep litter, drying in the deeper litter profile on a wet pad may never occur.

Experiment on density effects, University of Maryland.

Controlling the depth of litter is an important tool in managing litter temperatures. Rearing birds on wet, cold bedding can have major negative consequences on performance and carcass quality. With wet, cold, ammonia-laden built-up litter it is essential, particularly during cold-weather flocks, to preheat houses at least 24 to 48 hours prior to chick placement. A major integrator study in the Midwest reported their 10 best farms

had 0.67 percent 7-day mortality and the 10 worst farms 5.16 percent mortality. Litter temperatures during this period averaged 82 and 73°F for the best and worst farms, respectively. For all farms studied, there was a direct positive correlation between initial litter temperatures and livability. Managed properly, deep litter can benefit production by providing a greater insulating layer on the pad, allowing for greater moisture absorbency, and can generate heat in winter via its composting action. To reduce added heat load in houses from this built-up litter program in warm weather, it is becoming a common practice to reduce litter depth to approximately four inches by "cutting-the-centers" of houses. Litter is removed from the center of the house, often feed line to feed line, and the remaining litter from the sidewalls leveled out across the house.

Bacterial Growth and Ammonia

Wet litter also promotes bacterial growth, coccidial challenges, and disease risk. A study of commercial farms by Stayer, et al. (1995) found 12 times more cocci oocysts/g of feces on "poor" farms and the oocysts increased during the flock on these farms compared to "good" farms. The "poor" farms were identified as having wet litter due to poor drinker management and drainage. In a survey of Delmarva farms having an early respiratory disease challenge, Tablante, et al. (1998) found drinker age and layout time as factors influencing the challenge on farms. Compared to control farms, the challenged farms had older, worn nipple drinkers (5.2 vs. 4.9 years) and short layout times (15 vs. 17 days). One could speculate that the older nipples produced wetter litter resulting in a greater disease challenge.

Providing adequate layout time is a key tool in reducing disease challenge. This critical period in

a production cycle allows time for the litter to release moisture and ammonia, and for pathogens to die off. Layout time should not be measured from the day of movement, but from the day of crusting. Since cake is the most concentrated source of pathogens, moisture and ammonia in the house, effective and timely removal of this material is an essential component of a litter management program.

Finally, wet litter is strongly correlated with the production and release of ammonia. The negative effects of ammonia on broiler performance, health, and carcass quality have been well documented. Ideally, broilers should not be subjected to ammonia higher than 25 ppm. Maintaining desirable litter moisture and reducing litter pH are two means frequently used to reduce ammonia volatilization and bacterial populations in built-up litter. Chemical, microbial, and enzymatic litter treatments are tools used to reduce ammonia and/or bacterial populations. Selecting the best litter treatment is dependent on matching the characteristics of the product with your litter management goals. The acidifying litter treatments are the predominate amendments used by the poultry industry to suppress ammonia and reduce bacterial challenges during the brooding period. However, the following are reasons why these products may not perform to your expectations: uneven or timely applications, inadequate moisture for chemical activation, improper or inadequate ventilation following treatment, and insufficient amounts of chemical to meet the ammonia challenge in houses.

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The Impact of Air Quality on Pulmonary Dysfunction and Respiratory Infection

by Sabrina M. Brougher, Ph.D.

Overview

The poultry industry strives to maximize productivity in several ways, one of which is to increase stocking density. Although waste generation is unavoidable for large-scale poultry operations, a balance must be maintained between stocking density, housing conditions, and bird health, as high stocking density has been implicated in several negative welfare endpoints, including higher dust and ammonia, increased stress, and reduced immune function (2, 6), activity (5), performance, and welfare (13).

High ammonia remains a significant environmental problem for broiler farms. Substantial research focuses on nutrient management to facilitate the reduction of volatile ammonia levels in poultry houses, yet limited information documents the direct toxicological impact of ammonia on the health and well-being of the birds. Chronic human ammonia exposure limits are 25 ppm/d in Europe and 50 ppm/d in the U.S. (OSHA), yet levels above 45 ppm have been documented in poultry facilities (9). More importantly, human lung impairment at as low as 12 ppm chronic exposure manifests as chronic coughing/wheezing, bronchitis, and asthma. Compared to humans, flock exposure to inhaled toxicants (i.e., dust, ammonia, and bacteria) is elevated, in part, because they remain in the poultry house 24h/d (compared to 8h/d chronic human exposure) and also as a result of avian lung morphology, which is quite different from that of human lungs. Chicken lungs are structured as tubes, so as the bird inhales and exhales, the air continuously flows through the lung. As compared to humans, who have a lung structure more similar to an

inflatable balloon and are exposed to inhaled toxins on inhalation but not exhalation, the chickens' lungs are continuously exposed. This greatly increases the birds' sensitivity to poor air quality and can result in physiological, behavioral, and pathological changes.

Ammonia, lung quality, and disease susceptibility

High ammonia, poor housing conditions, and avian pulmonary morphology influence the chickens' risk of developing respiratory infections. It has been previously demonstrated that high ammonia causes increased lung pathogen exposure (12), reduced bacterial clearance, lowered resistance to respiratory infections (15), and tracheal and lung lesions (1, 2). Bird performance and welfare are currently determined by evaluating characteristics such as leg quality (3), behavior (7), corticosterone levels, heterophil-to-lymphocyte ratio (4), and mortalities (4). In addition, the detrimental effects of ammonia on pulmonary function should also be considered as a critical indicator of bird welfare, as the resultant increase in susceptibility to respiratory illness could potentially devastate an entire flock.

> *"High ammonia, poor housing conditions, and avian pulmonary morphology influence the chickens' risk of developing respiratory infections."*

It is important to investigate the effects of ammonia on lung physiology not only to evaluate bird health. Avian lung condition may correlate with human health risks associated with high chronic exposure to ammonia. Sampling of birds, combined with regular sampling of air quality, could provide a relevant overall picture of the levels of dust and ammonia exposure. In addition, housing and management improvements in response to the identification of substandard environmental housing conditions would benefit growers by increasing the performance of future flocks.

The National Chicken Council Welfare Guidelines (16) suggest a maximum allowable ammonia level of 25 ppm, with an ultimate goal of 10 ppm. More research is needed on the physiological, pathological, and behavioral changes in birds exposed to high levels of ammonia. Improved lung quality and reduced stress under low ammonia conditions could reduce susceptibility to respiratory pathogens and facilitate a reduction in the spread of avian pulmonary disease. This will help the poultry industry to determine management conditions to maximize production while improving health, well-being, and performance of the birds in a flock.

Symptoms that may indicate respiratory problems in your flock

The birds themselves can tell you a great deal about their condition according to how they are behaving in the house. Checking on your flocks on a regular, daily basis is the best way to monitor their health and the condition of your house. This will help to prevent more serious problems with environmental quality or disease. The more time you spend with your birds, the easier it will become to recognize the difference between a healthy and unhealthy flock. Keep in mind that if birds are experiencing respiratory distress from poor environmental housing conditions, this increases the overall risk of contracting more serious infections that can decimate an entire flock.

Monitor the behavior of your birds on a regular basis, and learn to recognize signs of respiratory distress or illness. These include changes in behavior such as labored breathing, swollen face and eyes, coughing, sneezing, lethargy, and poor appetite (14). Birds under high ammonia conditions may also tend to cluster near cleaner air, so if your flock is crowded near the fans at the end of your house they may be attempting to breathe cleaner air. Some individual birds may be more susceptible to respiratory problems than others, and they may be early indicators of disease. Early identification of these individuals could help you intercept a more serious problem with your flock. Remove any sick birds as soon as they are identified in order to avoid further infection, and consult with a poultry diagnostic service to identify the exact cause of the respiratory distress.

Methods to reduce ammonia and pathogen exposure

1. Modify the drinking behavior of your birds. The nipple drinkers will avoid spillage and reduce excessive time spent at the drinkers, but it is important to routinely maintain the drinking system. Adjust nipple drinkers to release water according to the age of the birds, and check for water leaks regularly. Ammonia is also a concern for broiler breeders, in particular since these birds are maintained in the house for much longer periods of time than are broilers. Some strains of broiler breeders are considered "wet" strains, spending an excessive amount of time at the drinkers. If this seems to be the case, consider regulating the access to water by turning the watering system on and off on a regular daily basis, but take care to ensure that this practice is done in a manner that does not stress the birds from lack of access to water, or else it may compromise productivity. This practice will work with broiler breeders but not with growing broilers because food intake is to some extent regulated by water intake.

2. Reduce the stocking density. Although your initial concern

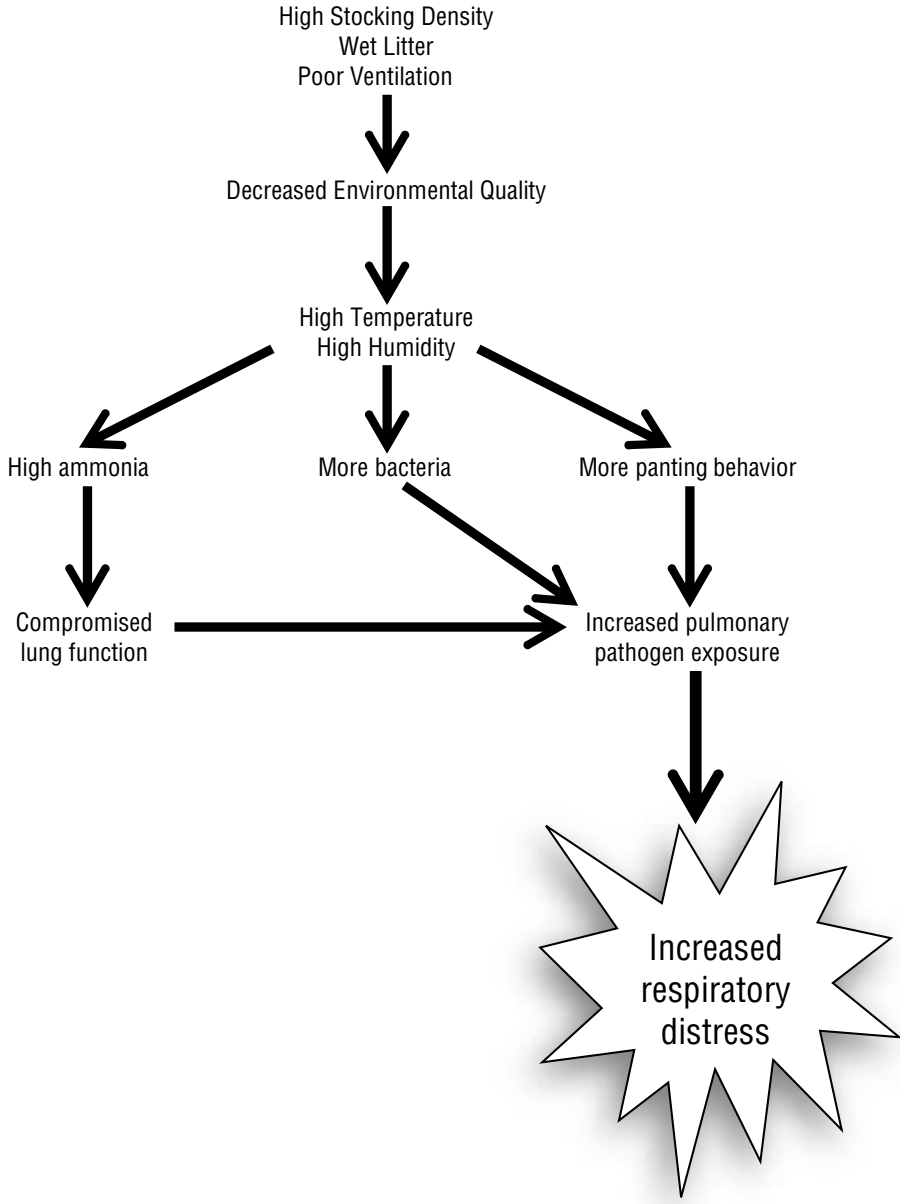

FIGURE 1. The cumulative effects of poor environmental housing conditions can greatly increase the occurrence of pulmonary dysfunction and disease, respiratory distress, and mortality in a broiler flock.

may be that raising a lower number of birds per growout flock will translate into reduced economic returns, high ammonia has been associated with reduced growth rate (19). Birds at a lower stocking density will be exposed to less ammonia and will likely be healthier, grow faster, and have higher performance rates.

3. Provide your birds with elevated regions of the house to escape high ammonia. Birds will modify their behavior accordingly (11), as laying hens have been previously shown to prefer control chambers to ammonia-contaminated chambers. Also, the addition of perches as an environmental enrichment technique has been suggested to alleviate heat stress and enhance welfare and broilers, because it allows the birds to utilize the vertical space and improve air flow as compared to birds on the floor of the house (8). In addition, birds housed at high ammonia may spend more time on elevated slatted floors, nest boxes and perches to seek regions of the house with lower ammonia than will birds maintained on clean litter substrate. Addition of perches or slatted platforms, particularly near the ventilated ends of the house, could provide your birds additional areas to escape the high ammonia levels on the litter floor. This will also improve air flow and increase litter exposure to air so it can dry out more quickly.

4. Carefully monitor environmental conditions, particularly temperature (17) and humidity. These two factors positively correlate with dust and ammonia concentrations as well as broiler mortalities (7). Elevated temperature will also cause your birds to pant, a response that will compromise their first line of immune defense. The nasal passage serves to filter out pathogens, but heat-stressed, panting birds instead breathe through their mouth, rather than their nose. This bypass of the nasal filtration system will increase respiratory tract pathogen exposure.

5. Keep an eye on the litter conditions, particularly if the litter is being used for more than one flock. Litter re-use increases both ammonia and bacterial levels. Rake litter well and allow ample time for it to dry out between flocks. The 2003 National Chicken Council Welfare Guidelines (16) recommend litter moisture below 35 percent. Look for mold and fungal growth. *Aspergillosis* is a fungal respiratory disease that causes lung lesions, and is found in moldy feed and litter. Do not reuse litter if your last flock had problems with ammonia or disease.

6. If ammonia levels tend to be elevated, you may want to take some greater measures to monitor and rectify the situation. Portable ammonia detection units are expensive investments, but close monitoring of ammonia could have a substantial payoff in the long run, translating into higher quality birds and increased productivity of your flocks. Monitoring pH of the litter would also be helpful, as high litter pH can also increase ammonia levels. A recommended litter treatment (18) to litter pH below 7.0 is the application of chemicals such as superphosphate (1.0 kg per 1 m^2), phosphoric acid (1.9 L per 1 m^2), or sodium bisulfate in the form of commercially available Poultry Litter Treatment (PLT; 10). PLT has been shown to reduce acidic litter, which, in turn, reduces ammonia and was reported to save up to $1600 per house in clean out, application, and litter-material costs (10).

> *"Elevated temperature will cause your birds to pant, a response that will compromise their first line of immune defense."*

Although close monitoring of your birds and the housing conditions may seem, at first, tedious and a waste of time, the long-term payoffs, in terms of productivity and animal welfare, will be well worth your time investment. Remember...ammonia impacts both you and your chickens! Any improvements in environmental quality will reduce your own exposure to airborne toxicants and will lower your risk of future respiratory illness.

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Balancing Economic and Welfare Aspects of Stocking Density

by Richard L. Lobb

Stocking density is a measure of how many chickens of a certain size are put in a growout house, given its size. Many factors affect the decision on stocking density, and it will not necessarily be exactly the same from flock to flock or house to house. Getting the stocking density right is important to the farmer to ensure proper return on his investment; to the integrator to meet its production targets; and, last but certainly not least, to the chickens themselves, to ensure their comfort and physical well-being.

It is sometimes said that a lower stocking density—fewer chickens in the house—is better from a welfare point of view. Some people have suggested that the broiler industry should utilize much lower stocking densities than are in use at the present time. However, this is not practical and not necessary for good animal welfare, as the facts will demonstrate.

What is animal welfare?

Any discussion of animal welfare should begin with a definition. After all, we can't figure out how to preserve animal welfare if we can't say what it is. Some people seem to try to determine if chickens are "happy." But this is obviously an attempt to apply human feelings and emotions to animals and is totally inappropriate in a production environment. If we want to apply human attributes, we should look at the criteria that are used to measure essential human welfare. These are, basically, the presence of a satisfactory nutritional status and the absence of disease. That is, are they getting enough to eat and are they healthy?

The feed given to broiler chickens is carefully formulated to meet their needs. Broilers get all the feed and water they want and gain weight at a steady and predictable rate. Under standard operating conditions, it would be hard to deny that their nutritional status is quite satisfactory.

Like any agricultural animals, chickens are subject to a wide variety of diseases, and finding ways to prevent, control, or eradicate these diseases has been a major objective of poultry scientists for many years. Chickens are vaccinated against common diseases and are treated when necessary. As a result, livability is over 95 percent of chickens placed. Total condemnations today are well below the level of the recent past—about 1.2 percent in 2003 compared with 1.5 percent in 1993. The health of the broiler chicken flock is probably at an all-time high.

All this has been accomplished despite the fact that overall density has increased from less than 5.6 pounds per square foot in 1988 to about 6.3 pounds per square foot in 2003. Higher density does not necessarily have a bad impact on broiler welfare. In fact, it is quite clear that broilers do very well in the density levels we have today and could do very well in higher density if certain aspects of the broiler environment are controlled.

Factors Affecting Stocking Density

In recent years, poultry producers and integrators have made many improvements to the broiler production environment that improve bird health and nutrition. These improvements are consistent with the economic needs of producers and integrators, and they are also consistent with improved animal welfare.

Tunnel ventilation: For example, tunnel ventilation, usually with cool cells, is now widespread in the industry. These systems keep the temperature in the growout house from reaching levels that cause heat stress. Since the first reaction of the birds to heat stress is to quit eating, controlling the temperature keeps the birds more comfortable and eating well. Tunnel ventilation also improves the atmosphere in the broiler house by removing ammonia, which is also good for the birds' overall welfare. Better air quality helps to reduce the occurrence of air sacculitis, a common disease of chickens.

Perhaps most importantly, however, tunnel ventilation and cool cells prevent the severe die-offs that can occur in extremely hot weather. Chickens lack the ability to perspire. They attempt to regulate their body heat mainly by panting. When the body temperature gets over 108 degrees, however, they are in trouble, and heavy mortality can occur in heat waves. This used to

happen sometimes during extreme and prolonged heat waves. By better controlling the temperature in the house, tunnel ventilation has virtually put an end to massive die-offs where it is used, so tunnel ventilation has to be considered a major improvement in animal welfare. By 2003, more than half the growout houses in the country had tunnel ventilation. Most of the new housing being built is tunnel housing, and many existing houses are being switched over.

Nipple waterers: In the old days, open troughs were used to carry water to the broilers. Since chickens are not housebroken, it was impossible to keep the troughs clean, meaning that the water could easily be contaminated by the time chickens got it. Also, spillage from the troughs meant wet litter, which contributes to foot problems, such as ammonia burns.

> *"Getting the stocking density right is important to the farmer to ensure proper return on his investment."*

The solution has been enclosed nipple drinkers, which deliver clean water to the chickens and result in much less spillage onto the litter, helping to keep it dry. Dry litter means far fewer foot problems, since wet litter leads to ammonia burns on the chickens' feet. Clean water, of course, helps limit the transmission of bacteria such as *Campylobacter*. Welfare again is served by technological improvements in the production environment.

Other improvements: Other steps taken to improve flock management have also made it feasible to utilize higher density levels. These include more efficient feeding systems, microprocessor control of equipment, litter treatments, and lighting programs. All these technological developments make the growout house environment more comfortable for broilers and enable the improved house to accommodate more birds with no loss in welfare as measured by nutritional status and absence of disease.

Determining Density

It is up to each broiler company to determine the best level of density for the particular type of bird and type of housing. Density varies especially according to the size of the bird. As the birds get bigger in terms of their target weight, they are given more space. These days, fast-food birds are typically being stocked at about 135 birds per 100 square feet, retail birds at about 125 per 100 square feet, and deboning birds at around 115 per 100 square feet. Thus, the larger birds are being given more room.

Scientific Research

A certain amount of scientific research has been conducted on the subject of stocking density and its role in animal welfare. However, much of this research has been done in Europe and relatively little in the United States. Conditions on broiler farms in Europe are quite different from those in the United States, so the usefulness of the research is somewhat limited.

For example, tunnel ventilation is not as common in Europe as it is here. Scientific articles based on research in Europe typically do not mention whether the houses being studied are tunnel-ventilated or not,

but it seems likely that most of them are not. Also, many of the houses in Europe have concrete floors, which tend to keep the litter much wetter than it is in American growout houses. Moisture is retained in the house rather than soaking into the ground as it is here.

A study published recently in the journal *Nature*, one of the most prestigious scientific journals in the world, has finally acknowledged that density, by itself, is not the only factor in animal welfare, or even the most important one. The authors say that differences in the production environment "have more impact on welfare" than stocking density itself. (1)

The findings of the study suggest that "stress on birds and their risk of dying depend on the extent to which companies can control the house environment." The authors found that the most important factors were the management of moisture in the litter and ammonia in the air. Those are exactly the areas in which American broiler housing is most different from European housing, because earthen floors, nipple drinkers, and tunnel ventilation keep the litter drier and the air better in U.S. houses.

Conclusion

Appropriate stocking density is largely a function of two parameters: first, the need of the producer to get the most use out of the investment he has made in broiler housing and equipment, and second, the welfare of the birds. Some people suggest that these parameters are necessarily going to be in conflict. In fact, experience shows that they work together. What's good for the economic needs of the producer is also good for the welfare of the birds. Dry litter, quality air, and clean water are all good for the efficient production of broilers that meet their weight targets. Technological improvements installed by many producers can help meet those objectives. At the same time, those factors are obviously good for the health, nutritional status, and general welfare of the birds. All these factors have to be taken into account in determining density, and arbitrarily low density limits should not be imposed.

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Stocking Density in Broilers: How many are too many?

By Inma Estevez

One of the most heated debates regarding broiler welfare is what should be the maximum density permitted in the U.S. to ensure bird welfare. In other words, how many birds are too many, to the point of compromising bird health and welfare? This is critical for the industry, as limitations on rearing densities will have a major economic impact. In this debate, a publication in the journal *Nature*, entitled "Chicken welfare is influenced more by housing conditions than by stocking density" by Marian Dawkins (Dawkins et al., 2004), has had major relevance. Her research provides scientific evidence that environmental conditions are more relevant to broiler welfare than stocking density *per se*. These results are not too surprising to some scientists who have argued that the environmental changes associated with increased density are a major factor affecting not only health and welfare but also performance of broilers. Because chicken houses can be managed differently and may have a wide range of ventilation, heating systems, litter management programs, etc., housing an identical number of birds per unit of area may be very different in different houses. It is, therefore, difficult to establish a precise number when recommending a limiting density. To determine the 'ideal' highest density to maximize productivity while maintaining adequate welfare we must consider a wide range of variables that should be included in a multifactorial equation. Such variables are: housing conditions, available equipment, litter management, quality of daily care, season of the year, location, etc. Having visited many farms I can appreciate not only the impact of state of the art equipment, but more importantly, what a tremendous difference a dedicated farmer who pays attention to the quality of the management and to the maintenance of good housing conditions makes to the birds. In addition to all the steps that can be taken to achieve better broiler welfare (that also will help tremendously to boost health

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and performance), we should not overlook the many publications that have repeatedly demonstrated the potential negative effects of density on broiler performance and welfare, when the assigned stocking density was inadequate according to the capacity of the facilities or to the quality of the management. The latter happens all too frequently.

Stocking Densities in Europe

If we look at the western European countries to get a sense of where to establish the upper limit of density, the range of variation is rather wide. It ranges from 30 kg/m^2 (6.13 lbs/ft^2) in Switzerland to 37 and 40 kg/m^2 (7.67 and 8.17 lbs/ft^2) in Germany and Denmark, respectively. In fact, the mean density in the U.S., according to the NCC, is 6.3 lbs/ft^2, only slightly higher than the density permitted in Switzerland, one of the toughest countries in terms of animal welfare legislation (they banned battery cages for laying hens in the 1980s). However, there are some important differences between the European and American rearing conditions; for example, in Europe, litter is entirely replaced and the house cleaned for each flock of birds and all the buildings are environmentally controlled. Therefore, the densities in the U.S. and Switzerland, although very similar in numbers, may not actually be comparable.

Acknowledging the fact that housing conditions and quality of management have a large impact on welfare, the Swedish welfare program for broilers, one of the most advanced European poultry welfare programs, bases the maximum permitted rearing density, which can range from 20 to 36 kg/m^2 (4.09 to 7.37 lbs/ft^2), on the results obtained by the farmers. If the producers obtain good welfare scores, they are permitted to maintain or increase stocking density to the next level. However, producers whose birds and facilities score poorly are required to reduce stocking density until they are able to improve the welfare scores. This program, created in 1980 by the Swedish Poultry Meat Association, is voluntary, although 98 percent of all farmers participate in it. Nowadays 72.6 percent of the farms are classified as maintaining 36 kg/m^2. Despite this high rearing density the incidence of severe foot pad dermatitis in Sweden has been reduced from 11 to 5 percent in three years. This has been made possible by producers becoming more aware of how management influences the health and welfare of the birds, and by farmers learning how to improve management routines so that they can keep higher densities.

"Closely monitoring humidity and temperature levels and their effects in performance can help companies and farmers better understand the dynamics of their farm environment."

How to Address Welfare Issues Related to Density

We all agree that environmental conditions are extremely relevant to poultry welfare. However, Dawkins' work cannot be interpreted as an excuse to dismiss the need for action when addressing density issues to maintain acceptable broiler welfare levels. When farmers are unable to maintain adequate environmental quality to insure minimum health and welfare standards, stocking density must be limited. Similar to the Swedish example mentioned above, Dawkins points out in her work that factors such as company and week of age of the birds explained 71.2 percent of the variation in humidity, which in her study was one of the most important factors affecting welfare levels. Clearly these two examples show that broiler companies would have in their hands the capacity to improve health and welfare levels by fine-tuning their management practices and housing conditions, and by adjusting environmental variables according to the biological needs of the birds. Companies have the power to educate growers to be more knowledgeable about management practices that improve heath and welfare, and they have the capacity to determine what is and is not acceptable in terms of animal care and negligence. Closely monitoring humidity and temperature levels and their effects in performance parameters throughout the year can go a long way in helping companies and farmers better understand the dynamics of their farm environment, permitting them to adjust and fine tune management practices. Even better, a large study of the effects of density under commercial conditions in the U.S. would determine what are the most critical factors hindering the performance, health, and welfare of American broiler production. This type of study may be extremely helpful in improving management practices, as some intricate relationships between factors may be revealed as in the Dawkins' study.

Uneven Bird Distribution

A factor that is not considered often enough when addressing density issues is that density may affect bird health and welfare even when stocking densities are not particularly high. Broiler chickens have a strong tendency to rest around walls, corners, migration barriers, or near farm equipment. This typical spatial distribution takes place even when plenty of space may still be available in the central areas of the house. Uneven distribution of birds within facilities may have important negative welfare consequences, even at

relatively low rearing densities. These consequences may include: 1) Reduced air flow between birds because of clumping, which can affect bird performance and their ability to cope with heat stress during the summer, increasing the risk of mortality; 2) Litter quality could be reduced in these highly used areas, which may result in an increased incidence of contact dermatitis, an important welfare indicator; 3) Chickens resting by the periphery of the house will experience high levels of disturbances from interactions with other birds. This behavior may result in reduced resting times, reduced performance, and an increased incidence of bruising and skin scratches that can easily become infected. Bird distribution can be improved by maintaining homogeneous temperature, ventilation, and lighting throughout the house (birds will tend to migrate to brighter areas) or by using protective devices to attract birds to less used areas. Walking close to the wall area during the daily inspection will also encourage birds to move to less frequently used areas with better litter quality. All these steps will help to alleviate excessive clumping of broilers in these preferred areas.

In summary, high environmental quality is far more important than density per se in order to maintain good health, performance and welfare, but companies and farmers must work together to insure that as stocking density is increased environmental control and quality of the care are stepped up accordingly. If this does not happen, then only by reducing density will we be able to guarantee an acceptable welfare level. In the real world we find these situations all too frequently. We also need to consider that health problems associated with high density may happen at relatively low densities if birds are unevenly distributed within the facility. This problem can be corrected by simple management practices.

So, to the question of how many birds are too many? The answer really is in the hands of every company and every farmer. The good news is that it is possible and relatively simple to increase welfare while maintaining acceptable density levels from the commercial standpoint, as we have seen in the Swedish example. It just takes time and interest from the companies and farmers to work on this matter. Is this going to be necessary? YES—welfare issues are here to stay and the sooner this matter is resolved the sooner we can move forward.

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