# Laying Hen Housing Research Project

## Summary Research Results Report, March 2015

Coalition for Sustainable Egg Supply

The Coalition for Sustainable Egg Supply is a multi-stakeholder group which collaborated on the Laying Hen Housing Research Project. The goal of this commercial-scale study of housing alternatives for egg-laying hens in North America was to understand the sustainability impacts of three laying hen housing systems – cage-free aviary, enriched colony and conventional cage.

The Coalition's research findings provide meaningful science-based data that will help guide future egg production and purchasing decisions.

The research assessed five areas of sustainability: Animal Health and Well-Being, Food Safety and Quality, Environmental Impact, Worker Health and Safety, and Food Affordability. The final research report, and this condensed version, each explore the sustainability interactions and trade-offs for these hen housing systems.

House Characteristics and Management

| | Conv. Cage | Aviary | Enriched |
|---|---|---|---|
| Dimension (L x W x H) | 464 x 84 x 20 ft | 506 x 70 x 10 ft | 506 x 45 x 13 ft |
| Hen breed | Lohmann White | | |
| Ave. no. hens at 19 weeks | 196,120 | 49,760 | 46,762 |
| Hens per cage | 6 | - | 60 |
| Designed space per bird, $in^2$ | 80* | 144 | 116 |
| Welfare enrichment elements | N/A | Perch, nest area, litter access | Perch, nest area, scratch pad |
| Ventilation type | Tunnel | Ceiling/perimeter slot inlets, Cross vent | |
| Manure handling | Manure belt | Manure belt + litter | Manure belt |
| Manure removal | every 3-4 days | Belt: every 3-4 days<br>Litter: end of flock | every 3-4 days |
| Photoperiod (Light:Dark) | 16:8 | | |

**The conventional cage system was comparable to other conventional cage systems widely used in the industry. In this case there were six hens per enclosure, with each hen provided 80 $in^2$ to meet customer requirements. While those specifications may differ somewhat from those of other North American egg producers, the research results nevertheless provide an indication of the trade-offs involved in using conventional cages.*

This research represents a snapshot in time – it assesses elements of hen housing and egg production using a single hen breed/strain, in a particular region of the U.S., over the course of three years and two flocks, in these particular housing systems. While it highlights the trade-offs involved and can assist in supporting informed decision-making, caution should be exercised in applying the research results to other scenarios with different variables.

### Animal Health and Well-Being

- Perches were well-used by the hens in both the aviary and enriched colony systems. Nests were also well-used in the enriched colonies, although nest use in the aviary was more variable. Nest pads in both systems stayed clean. Hens in the aviary dust bathed in the litter, whereas in the enriched colony hens used the scratch pad infrequently for dust bathing and foraging; it also became contaminated with manure.
- Pullets reared in the aviary rearing system had better bone quality of the humeri and tibiae, and this was maintained throughout the lay cycle. In contrast, aviary hens had more keel bone damage, which was already evident in aviary-reared pullets. Between 9 and 21% of flights in the aviary ended in failed landings, which could have contributed to the higher level of keel bone breakage.
- There were housing system-related differences in foot health and feather condition, with the enriched colony hens generally having problems intermediate between those of the conventional cage and aviary hens. The most common causes of mortality in all housing systems were egg yolk peritonitis and hypocalcemia. Hypocalcemia was more common in the aviary than conventional cages or enriched colonies and aviary hens that died were more likely to have been caught in the system, cannibalized, or pecked extensively than conventional cage or enriched colony hens.
- Physiological data did not demonstrate the presence of acute or chronic stress in any housing system.

#### PRODUCTION USE

Egg production through the first half of the flock cycles for each system remained fairly similar, with production from the aviary declining most through the remainder of the cycle. Average hen day production in the conventional cages was 3.5 to 4.8% less than the enriched colony, while the aviary was 4.3 to 6.7% less than the enriched colony system for the two flocks, respectively.

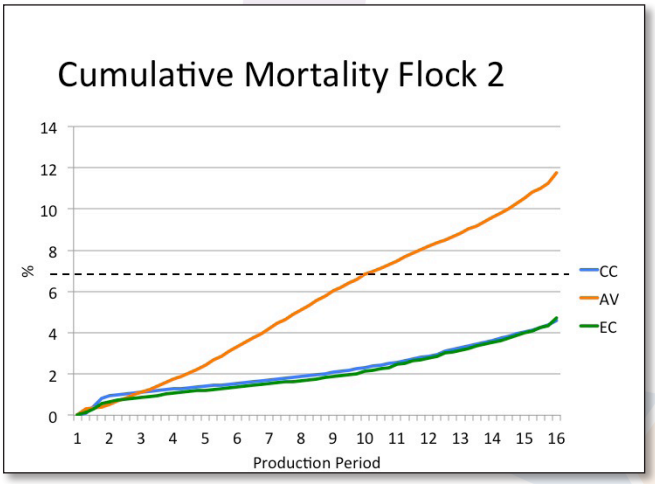
## Hen Production Performance

Noted as Flock 1/Flock 2

| Production Parameter | Conventional | Enriched | Aviary | Ref* |
|---|---|---|---|---|
| Cumulative Mortality (%) | 4.7/4.6 | 5.1/4.7 | 11.6/11.8 | 6.8 |
| Avg. Hen Day Prod (%) | 87.3/90.0 | 90.5/94.3 | 86.6/88.0 | 86.8 |
| Eggs Per Hen Housed | 352/371 | 363/382 | 340/345 | 354.2 |
| Water use, L/100 hen-day | 1.54/1.53 | 1.36/1.33 | 1.27/1.29 | - |
| Water/Feed, kg/kg | 2.06/2.05 | 1.73/1.76 | 1.64/1.74 | - |
| Feed Conversion (kg/Doz. eggs) | 1.44/1.40 | 1.42/1.38 | 1.49/1.44 | - |
| Feed Conversion (kg feed/kg egg) | 2.02/1.96 | 1.99/1.94 | 2.12/2.04 | 2.0-2.1 |
| Body Weight @ 78 wk (kg) | 1.56/1.67 | 1.55/1.59 | 1.53/1.60 | 1.71-1.86 |

*Lohmann LSL Classic White reference value

Hen mortality was much higher in the aviary system due to a variety of conditions, including hypocalcemia, egg yolk peritonitis, and to behavioral issues, with hens either being excessively pecked, or picked out (vent). There was less mortality in the enriched colony due to behavioral issues, and the least in the conventional system. There was the most egg yolk peritonitis in the conventional cages, less in the aviary and the least in the enriched colony. It was also harder to detect dead birds in the aviary and enriched colonies than in conventional cages.




### PHYSICAL ASSESSMENT

The research findings found that pullets reared in the aviary had better skeletal integrity than those reared in the conventional system.

Hens in the aviary and enriched colonies had a higher incidence of keel bone deviations and/or fractures than hens in the conventional cage system.

Conversely, hens in conventional cages had the highest incidence of foot problems, mainly hyperkeratosis. When hens in the aviary did have foot problems, they were more severe than those in the conventional cages or enriched colonies.

Hens in the conventional cages and enriched colonies had cleaner feathers but worse feather cover than those in the aviary. Patterns of feather loss suggested that hens in conventional cages and enriched colonies lost feathers due mainly to abrasion against the cage, while those in aviary lost feathers due to aggressive pecking from other birds. Hens with large areas of feather loss would be expected to lose more body heat than better-feathered hens.

### RESOURCE USE

All of the resources (perches, scratch pad, nests) in the enriched colony were used, but the perches and nests were overall better-used than the scratch pad. There was consistent low use of the perches during the day and high use at night. Use of the scratch pad for foraging and dust bathing was low, but hens did sit, stand and sleep on the pad. Use of the nest was high, with approximately 97% of eggs laid there. Nest pads stayed clean. However, eggs that were not laid in the nest were usually laid on the scratch pad, which became covered with manure over time.

Resources in the aviary were also well-used. Nest use was recorded in Flock 2 when hens were 19-36 weeks of age, and hens were found to lay their eggs in the nest approximately 97% of the time. At other times, however, there were periodic problems with eggs laid outside of nests, either on the floor in the litter or in other areas of the tiered enclosure. As in the enriched colony, the nest pads stayed clean. Hens used the internal perches extensively during the night, and particularly the perches in the top level. Hens used the open litter area to dust bathe most often in either afternoon or late morning. Hens were typically spread fairly evenly across the litter area, but were also seen to cluster there in large groups, with these 'piles' sometimes including as many as 229 hens and lasting for as long as six hours. Analysis of hen flight and landing success in the open litter area showed that failed landings were observed for 9.1-21% of flights, which could have contributed to the higher rates of keel breakage seen during the necropsies of aviary hens, since most failed landings were due to collisions with other hens.

### HEN PHYSICAL CONDITION AND HEALTH

Pullets were in good physical condition when they were placed regardless of whether they had been reared in an aviary or conventional pullet rearing system. Those reared in the aviary did have more keel abnormalities and dirtier feathers than conventionally-reared pullets, but also better foot condition as shown by less toe damage and shorter claws. For hens evaluated at 52 and 72 weeks of age, the conventional cage and aviary systems each had positive and negative effects

## Welfare Quality: Conclusions

| Measure | Conventional | Enriched | Aviary |
|---|---|---|---|
| Claw length | Intermediate | Shortest | Longest |
| Foot problems | Highest incidence | Intermediate incidence | Lowest incidence, but most severe |
| Keel abnormalities | Fewest | Intermediate | Most |
| Feather cleanliness | Relatively clean | Relatively clean | Dirtiest |
| Feather lipids | Highest | Intermediate | Lowest |
| Feather loss | Throat & belly | Throat, belly & head | Head |

on hen physical condition (e.g., a greater incidence of foot problems in conventional cages but foot problems most severe in the aviary; dirtier feathers in the aviary but largest amount of feather loss in conventional cages; highest incidence of keel abnormality in the aviary), with enriched colonies generally intermediate.

The tibiae and humeri of aviary-reared pullets had better load-bearing capacity and were stiffer than those of conventionally-reared pullets, indicating better bone quality and less susceptibility to bone breakage. This better bone quality was maintained in aviary hens through 72 weeks. Bone quality of the tibiae and humeri was generally better in enriched colonies than in conventional cages at 72 weeks, although not as good as in the aviary.

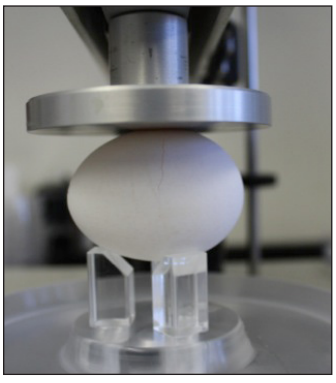
The main causes of mortality in all housing systems were hypocalcemia (low blood calcium levels) and egg yolk peritonitis (due to leakage of egg yolk into the abdominal cavity). Hypocalcemia was greatest in the aviary, with more than 3 times more hens affected in the aviary than in conventional cages and enriched colonies. Egg yolk peritonitis was greatest in the conventional cage house in Flock 1 while the aviary and enriched colony houses had equal numbers. For Flock 2, the conventional cage house and aviary house had equal numbers of egg yolk peritonitis while the enriched colony house had fewer birds with this condition. The aviary had the most hens that died from being caught in the structure, had been vent cannibalized (pick out) or excessively pecked, or that were emaciated in both flocks, while the conventional cage and enriched colony house were relatively equal in those categories.

### PHYSIOLOGICAL STRESS

Blood samples were taken for assessment of heterophil to lymphocyte ratios and white blood cell counts at pullet placement and then at peak, middle and end of lay; in addition, the hens sampled were euthanized and their adrenal glands were weighed. Overall, the physiological data were not suggestive of differences in long-term or short-term stress between the three housing systems.

## Food Safety

- Hens in all housing systems shed *Salmonella* spp. at a similar rate; the prevalence of *Salmonella* spp. associated with egg shells was very low and did not differ between systems.
- The highest environmental microbial levels were found in the aviary system litter area and on the enriched system scratch pad; aviary floor eggs also had significantly higher levels of microorganisms than all other types of eggs sampled.
- Housing system did not influence the rate of egg quality decline through 12 weeks of extended storage, and thus current U.S. egg quality standards and grades are adequate for all three of the housing systems.



Shell strength and other variables were measured to determine egg quality.

Researchers looked at the effect of housing type on hens' immune systems and *Salmonella* vaccination effectiveness. An effective immune response can result in a better resistance to invasion and colonization of *Salmonella* into tissues including ovary and eggs. The humoral and mucosal antibody levels of each flock were measured through ELISA measurement to determine immune status. Antibody response observed in serum samples and crop lavage extracts, as detected by ELISA readers, did not detect evidence of differences in hens between housing systems; however, significant seasonal differences were noted.

Through environmental and shell sampling, the prevalence of *Salmonella* and Campylobacter was monitored on collected samples from all three systems, with environmental dust levels influencing shell total aerobes. The aviary forage area and enriched colony scratch pads had the highest levels of total aerobes and coliforms, while aviary floor eggs had the highest total aerobes and coliform levels.

Hens from all housing systems shed *Salmonella* spp. at a high rate, between 89 and 100%. Also, the dry belt manure removal system impeded the detection of Campylobacter spp., as the manure was no longer a good environment for its detection. It's important to note that management practices likely had the greatest influence on environmental and egg shell microbiology.

Eggs from each of the three systems were also assessed for quality two days post-lay across multiple parameters, including measures of shell dynamic stiffness, egg weight, static compression shell strength, albumen height/Haugh unit, static compression vitelline membrane strength and elasticity, shell thickness, and whole egg total solids. It was determined that initial egg quality was not impacted by hen housing type, whereas hen dietary nutritional changes did.

Eggs were further assessed using these same measures at four, six and 12 weeks of cold storage to determine if housing system impacted the rate of egg quality decline. Findings showed the hen housing system did not impact the rate of egg quality decline over time. Current egg quality standards for retail and consumer storage before use, written for conventional egg production, should adequately define egg quality for commercial aviary and enriched systems.

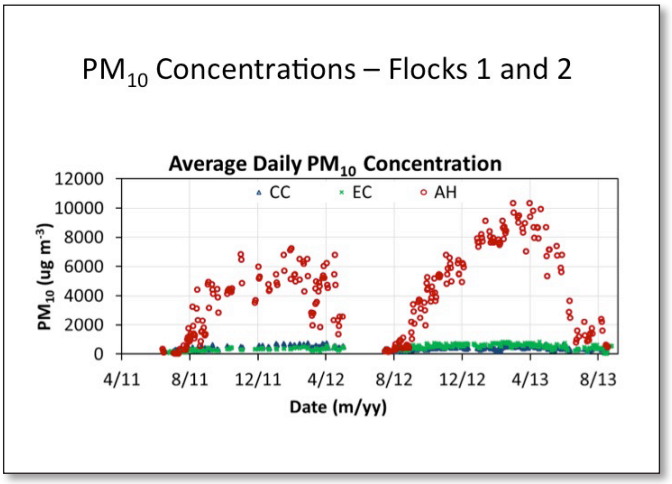
## Environmental Impact

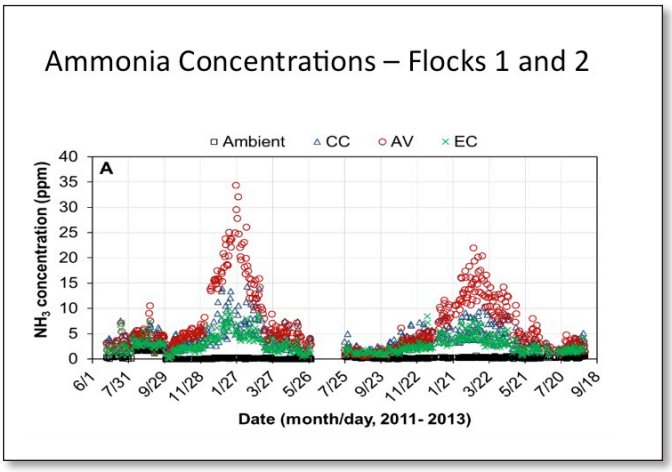
- Daily mean indoor ammonia concentrations, particulate matter (dust) levels and particulate matter emissions were all highest in the aviary house and lowest in conventional and enriched colony houses.
- Farm-level (house + manure storage) ammonia emission was lowest for the enriched colony system, approximately half that of conventional or aviary systems, presumably due to its lower stocking density and drier manure.
- In the aviary house, 77% of manure was deposited on the belts and the rest on the litter floor when hens had free access to that area. Manure removed from the enriched colony house was drier and had a slightly higher nitrogen content than that removed from conventional or aviary houses.

Research assessed the environmental characteristics of each of the three housing systems, including indoor air quality, air emissions, properties of the manure from the systems and energy use.

Regarding indoor air quality, ammonia and particulate matter (PM) concentrations were significantly higher in the aviary house than either the conventional or enriched house:

- Daily mean ammonia (NH3) concentrations were below 15 ppm in both conventional cage and enriched colony houses throughout the monitoring period, but higher ammonia concentrations in the aviary house resulted from accumulation of manure on the floor that was not removed until the end of the flock. Some days in the winter, ammonia concentration exceeded 25 ppm in the aviary house due to low building ventilation rate.
- PM levels in the aviary house were roughly eight to 10 times those in the conventional cage and enriched colony houses, which were by and large similar. Similarly, the aviary house had 6-7 times the PM emissions compared to the other two housing types. The higher PM levels and emissions in the aviary house were caused by hens performing activities on the litter floor.




Separate research assessed whether this dust and ammonia condition impacted worker health.

Ammonia emissions from manure storage accounted for about two-thirds of farm-level emissions. The enriched colony system had about one-half of the farm-level ammonia emissions as compared to the conventional and aviary systems, presumably due to its lower hen stocking density and drier manure.

Energy use and cost was similar across all three housing types. The aviary house required some supplemental heat (from propane) in the first flock, but not in the second flock. In all houses, operation of manure-drying blowers accounted for 55-75% of total electricity use throughout different seasons.

## Worker Health and Safety

- While working in the aviary house, workers were exposed to significantly higher concentrations of airborne particles and endotoxin (toxic components of bacteria) than when working in conventional and enriched houses; exposures in conventional and enriched houses were similar to one another.
- Though there was high mask use among all workers, short-term respiratory health was marginally worse, including lower lung function and more respiratory symptoms in the aviary versus the enriched or conventional houses.
- While tasks in each of the houses posed ergonomic challenges for the workers, gathering floor eggs in the aviary required them to adopt extreme body positions for extended periods and exposed them to multiple respiratory and ergonomic hazards because they had to crawl and lie on the floor.

Airborne particulate matter inside hen houses, depending on its size, can make its way into workers' airways, with smaller particles being deposited deep into the lungs. Endotoxin can promote airway irritation and inflammation, as well as decreased lung function.

To measure the impact of air quality on worker health, a total of 123 worker day data samples, with 41 samples from each of the three housing systems, were collected from workers who were randomly assigned to each house, ensuring equal coverage of each house. Each of those workers wore a personal exposure monitor while in the hen houses, sampling for ammonia, total suspended particles (TSP, also called inhalable) of all sizes and smaller particles up to 2.5 microns in size (PM2.5) through each of three seasons; summer, winter and spring.

Inhalable particle and PM2.5 concentrations, as well as endotoxin, were significantly higher in aviary house when compared to those in the conventional and enriched houses, which were similar to each other. It is believed these levels are highest in the

Employees participated in respiratory analyses, measuring lung function and exhaled nitric oxide.

aviary house due to litter (dust bathing material and manure) left on the floor.

Across the three seasons tested, spring, summer and winter, the aviary had higher inhalable concentrations, PM2.5 concentrations, inhalable endotoxin and PM2.5 endotoxin, with one exception. Only during the summer were PM2.5 endotoxin nearly equal across each of the three housing types.

The detection of ammonia was also highest in the aviary house during the summer, while winter and spring testing showed no significant differences between housing types. The percentage of time the ammonia was greater than or equal to 25 ppm, the National Institute for Occupational Safety and Health's (NIOSH) Recommended Exposure Limit, was highest in the enriched and aviary houses. Given the percentage of time exposure occurred at that level, this was a relatively low exposure rate, making any potential health impact insignificant.
Lung function and exhaled nitric oxide, both tests of possible airway inflammation were measured, along with self-reported occurrence of respiratory symptoms. Changes in lung function and exhaled nitric oxide were similar across housing types. Average mask use was higher for those workers in the aviary house, which may have protected them from greater respiratory consequences.

Worker ergonomics were also considered, with tasks classified into three categories indicating their level of ergonomic risk due to body position during the task. Researchers also looked for three main ergonomic stressors, including force, repetition, and posture.

In the ergonomic review, a number of tasks stood out as possible risks. Loading and unloading of cages in the conventional cage and enriched colony houses during population and de-population required extreme body positions, including squatting for an extended time. There was also significant twisting while "herding" the birds and standing on small diameter railings in these two houses.

Gathering eggs that had been laid on the floor in the aviary house was also noted as an issue, as it warranted extreme body positions, including squatting for an extended period of time. Further, extreme arm positions over the shoulder and reaching to the side, as well as rapid and extreme hand and wrist positions were noted. Crawling and lying on the floor to collect floor eggs also exposes the employees to potential respiratory hazards, especially if no respiratory protection is worn, as well as to potential infection hazards to the hands and the knees.

## Food Affordability

- At 10% interest and depreciation, the aviary system had total capital costs per dozen eggs that were 179% higher than the conventional cage system, while the enriched colony system had total capital costs per dozen eggs that were 106% higher than conventional cage.
- The aviary system had total operating costs per dozen eggs that were 23% higher than the conventional system, while the enriched system had total operating costs per dozen eggs that were 4% higher than conventional.
- The aviary system had total costs per dozen eggs that were 36% higher than the conventional system, while the enriched system had total costs per dozen eggs that were 13% higher than conventional.

Feed comprised the largest share of operating costs for each of the housing systems. While feed consumption per hen was similar across the systems, it increased over the life of the flock and was more costly per dozen eggs produced in the aviary system because production per living hen in that system declined more over the life of the flock than in other systems.

Labor costs were highest in the aviary system. The enriched system had higher routine labor weekly costs than the conventional cage system, though they did not rise over the life of the flock like in aviary. An enriched colony system with more hens may be efficient and reduce labor costs per dozen eggs produced.

Operating and Capital Costs per Dozen Eggs – Flocks 1 and 2

| | *Conventional* | *Aviary* | *Enriched* |
|---|---|---|---|
| Feed cost | $0.425 | $0.436 | $0.417 |
| Pullet cost | $0.148 | $0.221 | $0.143 |
| Labor cost | $0.019 | $0.074 | $0.056 |
| Energy cost | $0.014 | $0.015 | $0.014 |
| Misc. cost | $0.005 | $0.005 | $0.005 |
| Total operating costs | $0.612 | $0.751 | $0.636 |
| Capital costs (at 10%) | $0.058 | $0.162 | $0.120 |
| Sum of capital and variable costs | $0.670 | $0.913 | $0.756 |
| Percentage higher costs compared to conventional | -- | 36% | 13% |

Costs per pullet were also substantially higher for the aviary system, due to higher rearing costs coupled with higher mortality and lower production in that system.

Energy and other miscellaneous costs, such as general supplies and house-specific repair costs, were consistent across the systems and made up a very small percentage of the overall costs associated with production.

Overall operating costs per dozen were substantially higher for the aviary system and only slightly higher for the enriched colony system compared to the conventional cage system.

Capital costs per dozen were much higher for aviary and enriched colony systems than the conventional cage system because of the costs associated with construction of those barns and the relatively few hens housed in each, compared to the conventional housing.

In total and driven largely by higher feed, labor, pullet, and capital costs, the aviary system was 36% more expensive to produce eggs in than the conventional cage system, while the enriched colony system was 13% more expensive than conventional cage, primarily due to capital costs per dozen.