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Article

Specialized chicken toys are effective in relieving stagnant egg production in stressed layer hens

Anika Nawar[1,2], Sahin Sultana[3]

[1] STEM, Granada Hills Charter High School, Granada Hills, California

[2] Free Feathers Foundation

[3] Granada Hills Charter High School, Granada Hills, California

SUMMARY

Chickens are becoming common household pets in the United States. Although they provide eggs and companionship, they also invite additional financial strains resulting from common health issues, such as stress. In chickens, stress can appear as behavioral fatigue and an overall lethargic physical appearance. We examined associations between laying hens' distressed behavior, interactions with specialized handmade chicken toys, and resulting egg production rates. Knowing that chickens may be naturally drawn to colorful items and interaction with them can combat stress, we hypothesize that stressed hens who interact with Free Feathers Foundation's handmade chicken toys for three weeks will yield higher egg production rates at the end of that period than hens who do not have access to such enrichment. We observed at two different test locations that there was a statistically significant difference in egg production rates between stressed hens who received specialized chicken toys and those who did not. Hens who were part of the experimental groups and received enrichment demonstrated higher average egg counts per week as opposed to the control groups which received no toys during the interaction period. Statistically significant differences between each group's initial and final egg production rates (number of eggs per week) and behaviors were observed when chickens interacted with the handmade toys. Free Feathers Foundation's handcrafted toys may be cost-effective alternatives for inaccessible enrichment options for low-income chicken owners if their hens are suffering from stress, which may boost egg production for initially stagnant egg producers.

Conflict of Interest Statement

Anika Nawar is the Founder of Free Feathers Foundation and creator of the ChickFlicks used in this study. The remaining authors have no conflicts of interest to declare.

INTRODUCTION

Domesticated hens often face extreme health issues throughout the body, from visible wounds to chronic mental stress, which inhibits the egg production system (1). Stress in chickens is defined as the biological response to environmental stimuli that the chicken may determine to be harmful or fear-inducing (2). Such stressors are often natural and inevitable, such as nearby predators, high temperatures, or the demanding energy needed to lay eggs and raise chicks (3). Other stressors depend on the owner's provisions, including unhealthy diets, small living spaces, dirty litter, rehoming, or vaccinations (3, 4). As a result, the chicken will display behavioral and physiological symptoms (5). Behavioral symptoms include reduced physical activity, oversleeping, decreased attentiveness and escape reflex, separation from flockmates, and an overall "depressed look" (5). Physical symptoms include drooped tail, tucked head, partially or fully-closed eyes, panting, partially or fully-open beak, drooped wings, hunched posture, ruffled feathers, and crouched positions (5). These symptoms are detrimental and will deplete the chicken's health and ability to protect itself, posing a serious animal welfare issue (5).

This state of distress and despondency is not only a challenge for chickens, but also their owners. Local chicken ownership in the United States is on the rise, with 13% of households owning pet chickens as of 2020, which is an 8% increase since 2018 (6). With an estimated population of 85 million, chickens are the third most popular household pet in the country (6). Given the large population of pet chickens, there must also be a large population of owners who depend on their pets for companionship and egg production (7). Stress in chickens is associated with elevated levels of corticosterone, a hormone tied to decreased egg production (2, 8). Thus, unsolved stress for their chickens would diminish their pets' health and ability to behave as company, leading to the loss of affectionate relationships and food sources.

Antidepressants provide a straight path to poultry welfare, especially if it can prevent symptoms of stress. Sertraline is one anti-depressant that can be used in chickens; however, a previous study showed that high-dose treatment, four times the approved level in humans, resulted in an increase of *Escherichia coli* present within various organs in chickens (9). Correct dosage can depend on the hen's weight and/or the bioavailability of the antidepressant and may be hard to estimate. Other studies have validated alternative sources of enrichment for chickens to decrease stress levels, susceptibility, or egg production depression. Dietary supplements like 50-75% Mn-methionine can increase egg production and quality, concentrated yeast fermentation

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products can reduce stress susceptibility, and vitamin and micromineral additives decrease stress and optimize production (4, 10, 11). Physical changes to their living conditions may also prevent stress. Perches, scratching pads, and suspended CDs provide enough enrichment to boost their welfare, laying performance, and decrease symptoms of stress (12).

While solutions are available, they may not be easily attainable for chicken owners. Dietary supplements, especially minerals, may be expensive or hard to locate in local feed stores, and the digital divide may prevent other owners from accessing delivery options. Similarly, scratching pads and nontoxic perches are specialized for chicken usage, and may also be inexpensive but inaccessible for the same reason. While suspended CDs are inexpensive and common household items, windy conditions may turn them into safety hazards near chickens due to potential swinging and hitting, meaning it may not be a suitable option at all times.

The lack of accessible solutions for chicken stress is especially problematic for low-income chicken owners, as they might not be able to afford enrichment products. Inevitably, if their chickens' despondency goes unresolved, then owners will lose eggs and will need to turn to store-bought eggs, spend more money on veterinary care, or replace non-laying hens with healthier ones. This often fruitless routine only lowers the owners' income further while also providing no relief for their chickens. Thus, there is a need to measure the effectiveness of alternative, inexpensive solutions to relieving poultry stress and consequent stagnant egg production, such as easily accessible crafts.

Specialized chicken toys may be an effective, low-cost solution to stress and stagnant egg production as long as they are colorful and vary in shape. The interwoven patterns of light receptors in chicken eyes maximize their ability to perceive many more colors than most mammals can, leading to extra sensitivity to color (13). Such an ability can trigger pecking, connected to their natural foraging instincts (14). Chicks prefer saturated colors, pecking more often at saturated hues of orange specks over blue specks and saturated hues of green specks over red specks (14). Chicks also prefer prey-shaped objects over round objects, which may connect dietary habits to pecking behavior (15). Although these preferences apply to young chicks, color and shape preference in laying hens is understudied, so it is unconfirmed if grown chickens still maintain such preferences.

Nonetheless, harmless pecking at colorful and shaped objects may indicate "positive affect" (16). Enrichment objects that require activity can promote play behavior, which may improve poultry welfare, such as activity, stress, and despondency (16). If chicken toys can be developed to fulfill the role of enrichment, then low-income chicken owners may find an inexpensive, easily craftable solution to their pets' stress. We therefore aimed to quantitatively explore the effect of stressed hens' interactions with chicken toys and their resulting egg production rates. By organizing a control group of hens with no treatment and an experimental group of hens that would have access to chicken toys, their egg production rates could be compared.

We hypothesized that stressed hens who exhibit play behavior with specialized handmade chicken toys will yield higher egg production rates than hens who do not have access to such enrichment. Ten hens of varying breeds received no toys while ten other hens of varying breeds received Free Feathers Foundation's handmade chicken toys to play with for three weeks and each hen's number of eggs produced was collected daily after the three-week period, in addition to notes of behavior. After data collection, hens who played with the handmade toys had higher egg counts than those who did not and exhibited reduced symptoms of stress. Future research objectives should investigate the toys' effectiveness on specific breeds or chicken genders, or test for egg quality rather than product rates.

RESULTS

The first location that we classified for data collection was Farm 1. Out of the 52 hens, we classified 26 hens of varying breeds as stressed according to the observed symptoms of the Stressed Chicken Scale (5). Each coop had sufficient room for at least 10 hens. We randomly assigned each stressed hen to the experimental group or control group and placed those 10 hens in corresponding group cages. We recorded both groups' initial egg production rates (number of eggs per week) and behavior before a three-week waiting period, which was necessary for the experimental group hens to get accustomed to the chicken toys and for all hens to get used to the environment of their newly assigned cages. The waiting period after the introduction of the toys would last three weeks for both groups, before we recorded final egg counts. Both groups' varying breeds consisted of Araucana, Australorp, Isa Brown, Minorca, New Hampshire Red, Rhode Island Red, Orpington, Silkie, Sussex, and Wyandotte. Combinations were unique to each group. Because these individual hens were already housed together before this study, they were used to each other's presence, preventing the unique breed combinations from adding stress. This broad range of breeds also allowed for generalization among different chicken breeds so that the research would not only apply to one single type of chicken.

Location 1: Egg Laying Rates

For Farm 1, using the owners' available resources, the 10 control group hens were placed in a 5-ft by 7-ft standard chicken coop with open cage space, two 3-gallon water feeders, and two 7-pound feeders of chicken scratch, and the 10 experimental group hens had the same conditions in a separate coop. Food and water were refreshed every month, so no human-and-chicken coexistence occurred during the data collection periods.

For Farm 1, the control group showed no difference between the means of eggs produced by stressed hens before and after the three-week waiting period. The control group's egg counts averaged 0.6 ± 0.843 eggs before the waiting period and showed no change after the waiting period (**Table 1**). In contrast, the experimental group showed a notable difference between the means of eggs produced by stressed hens before and after the three-week waiting period. The experimental group's egg counts averaged 0.8 ±0.844 eggs before the waiting period and 3.0 ±1.333 eggs after the waiting period, indicating an increase in egg count averages (**Table 1**). This difference in egg counts for the experimental group was significant ($p < 0.05$, paired t-test).

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Control Group				Experimental Group			
Breed	Eggs per week before waiting period	Eggs per week after waiting period	Difference in Egg Production	Breed	Eggs per week before waiting period	Eggs per week after waiting period	Difference in Egg Production
Araucana	0	0	0	Araucana	0	3	3
Araucana	0	0	0	Australorp	2	3	1
Isa Brown	1	1	0	Isa Brown	1	4	3
Minorca	0	0	0	Isa Brown	0	3	3
NH Red	2	2	0	NH Red	2	4	2
RI Red	1	1	0	NH Red	2	5	3
Silkie	0	0	0	Orpington	0	2	2
Silkie	0	0	0	Silkie	0	2	2
Silkie	2	2	0	Sussex	1	3	2
Wyandotte	0	0	0	Sussex	0	1	1

Table 1. Control and Experimental Groups at Farm 1. Hens' breeds, initial egg production rates per week, and post-waiting period egg production rates for both groups. Control group showed no statistical difference in egg production ($p = 1$) while the experimental group did show a difference ($p < 0.001$).

Control Group				Experimental Group			
Breed	Eggs per week before waiting period	Eggs per week after waiting period	Difference in Egg Production	Breed	Eggs per week before waiting period	Eggs per week after waiting period	Difference in Egg Production
Isa Brown	3	3	0	Araucana	2	2	0
Isa Brown	2	2	0	Australorp	3	4	1
Isa Brown	0	0	0	Australorp	2	4	2
NH Red	2	2	0	Minorca	1	3	2
NH Red	2	2	0	NH Red	0	2	2
RI Red	3	3	0	RI Red	0	3	3
Orpington	0	0	0	Orpington	0	1	1
Sussex	0	0	0	Orpington	0	1	1
Wyandotte	0	0	0	Wyandotte	0	2	2
Wyandotte	0	0	0	Wyandotte	1	3	2

Table 2. Experimental and Control Groups at Farm 2. Hens' breeds, initial egg production rates per week, and post-waiting period egg production rates for both groups. Control group showed no statistical difference in egg production ($p = 1$) while the experimental group did show a difference ($p < 0.01$).

Location 2: Egg Laying Rates

The second location that was classified for data collection was Farm 2. Using the owners' available resources, the 10 control group hens were placed in a 6-ft by 10-ft standard chicken coop with open cage space, two 3-gallon water feeders, and two 7-pound feeders of chicken scratch, and the 10 experimental group hens had the same conditions in a separate coop. Throughout the three weeks of toy interaction, both groups at Farm 2 experienced about two minutes of human-and-chicken coexistence as Farm 2's staff had to refresh their water and food feeders, but the hens were already accustomed to this person's presence due to constant interactions and bonds formed prior to the research. The method for randomly assigning and obtaining data was the same for this location as it was in Location 1. Once again, we used the same breeds used in Location 1, as these are common breeds in the US. For Farm 2, the control group showed no difference between the means of eggs produced by stressed hens before and after the three-week waiting period. Like with Farm 1, the control group's egg counts did not change from between before to after the waiting period (1.2 ± 1.317 eggs, **Table 2**). However, the experimental group showed a striking difference between the means of eggs produced by stressed hens before and after the three-week waiting period. The experimental group's egg counts averaged at 0.9 ± 1.101 eggs before the waiting period and 2.5 ± 1.080 eggs after the waiting period, conveying an increase in egg count averages (**Table 2**). This difference in egg counts for the experimental group was significant ($p < 0.05$, paired t-test).

Breed-by-Breed Egg Laying Rates

We then compared pre- and post-toy egg counts for every single breed as breeds vary in temperament which may impact how they interact with any toys present. Overall, seven out of ten chicken breeds (Australorp, Isa Brown, Minorca, NH Red, RI Red, Silkie, Wyandotte) showed statistically significant differences in egg laying before and after playing with the chicken toys ($p < 0.05$). There were no significant differences in Araucana, Orpington, and Sussex experimental groups or the ten control groups (**Tables 1-2**).

Observed Behavioral Results

We also observed every hen's behavior before and after the waiting period of three weeks. This allowed us to look at stress symptoms before and after toy interaction for experimental groups, and the difference in behavior between the control and experimental groups (**Tables 3-6**). We saw that both test locations' control groups showed almost no difference in behavior before and after the waiting period – they remained inactive, isolated, and mute (**Tables 3, 5**). On the other hand, both test locations' experimental groups did show more active performance after the waiting period (during which they became accustomed to the presence of the handmade chicken toys) (**Tables 4, 6**). Overall, the toys appeared to decrease behaviors in the hens associated with stress and despondency.

DISCUSSION

We found that hens that had an interaction period with the enrichment had higher egg production rates and improved behavior at the end of the period than hens who did not have those toys. Social behavior is common in healthy domesticated hens, which can include vocalization and nearness to other flockmates (5). Not only did the handcrafted toys increase egg production for the hens, but it also decreased stress symptoms as experimental group hens displayed the healthy socialization symptoms. Our results indicate that brightly colored toys may be an alternative, inexpensive solution to poultry stress for low-income hen owners as we saw increased egg production after interaction with the toys. Reduced egg production can be a measure of poultry stress as egg stagnation is seen with stress in hens (2).

Although these results point towards the chicken toys being effective in relieving poultry stress and consequent egg production, it is imperative to note that the data is not fully inclusive of the global chicken population. We did not find any significance in quantitative data for the Araucana, Orpington, and Sussex experimental groups or the ten control groups. Owners of those three specific breeds may see that the enrichment is not as effective as an enrichment alternative for their hens when it comes to egg production. Nonetheless, behavioral results indicate decreased symptoms of stress for

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Breed	Behavior Before 3-Week Waiting Period	Behavior After 3-Week Waiting Period
Araucana	some movement, observed skipping mealtime everyday	still skipping meals, less motor actions and opts to sit still
Araucana	little movement, some sounds, pale facial skin	continuation of little movement, only about 2 clucks per 15 mins
Isa Brown	active movement, no sounds, lacks self-grooming, isolated from rest of flock	more movement (seven steps in 15 mins), clucked 3 times in 15 mins
Minorca	little movement, some sounds, stays near thick of flock	little movement, some sounds
NH Red	some movement, silent, has 1 friend nearby	still stays close to buddy
RI Red	active clucking, lacks self-grooming, active movement, has a few friends	little movement, no sounds
Silkie	active movement, no sounds, isolated from flock, no self-grooming	continuation of behaviors like little movement, no sounds
Silkie	moderately active movement, observed skipping mealtime everyday	little movement, no sounds, few pecks per meal
Silkie	little movement, no sounds	little movement, no sounds
Wyandotte	complete isolation from flock, not active throughout day, needed to be force-fed	isolated from flock, skipped meals, less active

Table 3. Control group behavior at Farm 1. Hens' breeds, initial notes of behavior, and post-waiting period notes of behavior.

Breed	Behavior Before 3-Week Waiting Period	Behavior After 3-Week Waiting Period
Araucana	little movement, no sounds, eats 1 meal per day, not isolated	broody hen, clucks often, socializes with 1 friend seemingly
Australorp	a little active, surrounded by few companions, no sounds	actively moves around often, still has companions & socializes
Isa Brown	very skinny (skipping meals), little movement, some sounds	curiously pecks at toys every day, eats a bit more often, some sounds
Isa Brown	no movement, seems to follow 1 companion, some sounds	actively pecks at food & toys, very noisy now, socializes with 2 friends
NH Red	some movement, lacks self-grooming, sitting often, no sounds	broody hen, clucks, socializes
NH Red	isolated, sitting 7 hours straight, not self-grooming, sneezing often	plays with toys every day, still sneezing, more in thick of flock
Orpington	lacks self-grooming, not even standing often, still eats often	moves around more often, eating 3 meals per day healthily
Silkie	isolated from flock, lays no eggs, little to no clucks	actively moving around often, clucks often, socializes with many
Sussex	little movement, some sounds, lacks self-grooming	active sometimes, clucks often, socializes with a few (4) friends
Sussex	appearance is health but only some movement, some sounds	actively pecks at toys but still silent, has 1 friend

Table 4. Experimental group behavior at Farm 1. Hens' breeds, initial notes of behavior, and post-playing period notes of behavior.

those breeds after playing with the toys (**Tables 3-6**).

Additionally, only ten out of hundreds of globally recognized chicken breeds were included in the data. Each breed has their unique traits, such as varying ranges of docility, aggressiveness, and egg-laying abilities, which may impact which types of hens tend to be attracted to the handmade toys (17). Use of the handmade chicken toys may not be enough alone to remedy stress exposure. Surveying the hens' physical environment to reduce any possible stressors can be a preventative measure, should the hen display distressed behavior. For example, living spaces that are too small may stress chickens out, as hens housed in large conventional cages and free range environments show higher egg production, which may be tied to lower stress levels (18).

It is also important to note that there are many factors that impact egg production, including feed consumption, water intake, intensity and duration of light received, health history, and management (19, 20). As such, many factors as possible were controlled during this study, including the amount of food and water offered to the hens, the time of year during which the study was conducted, molting patterns noted, and normal management routines. However, we only looked at egg production in relation to poultry stress, specifically in visibly stressed hens, as classified by their behaviors and appearances based on an outlined chart of symptoms. Conveyed by collected results, only chickens who received handmade toys improved their behaviors to include more socialization and self-maintenance as opposed to their prior states of isolation and fatigue. Future studies may be more informative by focusing on alternative factors of egg production, such as egg quality or consistency in seasonal egg production. They may even expand knowledge in this subject by finding the effectiveness of handmade chicken toys on poultry stress for roosters in terms of behavior and mental health instead of egg production.

MATERIALS AND METHODS

Study Population

Data was collected from two test locations to include a diverse representation of hens in different environments. Farm 1 was located in urban Downtown Los Angeles, and Farm 2 was located in the rural mountain range of Sun Village, California. Both these farms reported frequent symptoms of poultry stress in their hens prior to data collection. Before data collection, hens were assessed at each location for distressed behavior, according to the Stressed Chicken Scale (5). Ten hens of varying breeds were included in each experimental and control group per test location. The control groups consisted of stressed hens of varying breeds who received no chicken toys and the experimental group consisted of stressed hens who received Free Feathers Foundation's handcrafted Prototype #3 toys.

At Farm 1, the owner verified that none of the 20 randomly selected hens had faced any serious health issues in the past, besides the common Bumblefoot (pododermatitis) infection for the Silkie and Araucana in the experimental group and the RI Red in the control group. All three cases were treated within the past year. At Farm 2, the owner similarly stated that none of the 20 randomly selected hens faced any serious or life-threatening issues in their history, but the one Orpington in the control group got Bumblefoot within the past year.

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Breed	Behavior Before 3-Week Waiting Period	Behavior After 3-Week Waiting Period
Isa Brown	some movement, observed skipping mealtime every day	little movement, some sounds
Isa Brown	little movement, some sounds	still not very active and makes little to no sounds
Isa Brown	little movement, no sounds	continuation of behaviors - little to no clucks or movement
NH Red	active, playful with others but always silent	active, very social & clucks a bit more often
NH Red	isolated from flock, lays few eggs, little to no clucks	continued behaviors, still few eggs
RI Red	actively moves around sometimes, silent & no self-grooming	still lacks self-grooming, sitting often, no sounds
Orpington	some movement, no sounds	almost no movement, no sounds
Sussex	moderately active movement, observed skipping mealtime every day	little movement, some sounds, still eating less often
Wyandotte	no movement, seems to follow 1 companion, some sounds	still stays close to buddy but has gone fully silent
Wyandotte	isolated from flock, lays no eggs, little to no clucks	continued behaviors & is still silent

Table 5. Control group behavior at Farm 2. Hens' breeds, initial notes of behavior, and post-waiting period notes of behavior.

Breed	Behavior Before 3-Week Waiting Period	Behavior After 3-Week Waiting Period
Araucana	little movement, some sounds, stays near thick of flock	still is immersed in flock & seems social, more active & clucky
Australorp	active movement, some sounds, has 1 companion	actively pecks at food & toys, very clucky now, broody
Australorp	no movement, seems to follow 1 companion, some sounds	still has 1 companion but socializes with her more & active
Minorca	little movement, some sounds	very active, clucks often during day
NH Red	isolated, sitting 4 hrs straight, not self-grooming	grooming sometimes now, moves around a bit more near friends
RI Red	moderately active movement, observed skipping meals	broody, clucks very often, socializes while eating often
Orpington	isolation from flock, not active throughout day, not eating often	eating more often, still seems a little isolated, pecks at toys
Orpington	no movement, observed skipping mealtime everyday	eating more healthily, moves around more often, clucks often
Wyandotte	little movement, some sounds, not very isolated though	active, clucks, socializes with few friends, broody
Wyandotte	lacks self-grooming, not even standing often, still eats often	actively moving around often, clucks often, socializes w/ many

Table 6. Experimental group behavior at Farm 2. Hens' breeds, initial notes of behavior, and post-waiting period notes of behavior.

Measures

Free Feathers Foundation's handmade chicken toy (Prototype #3, "ChickFlicks") attracted the most attention from hens during pre-research observation time periods. The toy was made of red and green tulle fabric bunched into layers, tied off with red string to form a bow-tie shape (**Figure 1**). From the center hung three ceramic star beads, varying in color, while two synthetic feathers jutted from the top of the bow shape, also varying in color. The product was lightweight, small, and contained saturated colors and varying shapes. Egg production rate (measured in number of eggs per week), was recorded as a proxy for measuring the hens' stress severity after interacting with the toys.

Figure 1. Free Feathers Foundation's ChickFlick. This is the official specialized chicken toy (Prototype #3) that was given to the experimental groups at Farm 1 and 2 for enrichment.

Procedure

Before data collection, all 44 hens at Farm 1 and all 52 hens at Farm 2 were assessed for stressed behavior with the Stressed Chicken Scale (5). This set up criteria that each hen must meet to be classified as stressed, shown through behaviors and body positions. Behaviors include isolation from the flock, oversleeping, and little movement (5). Body position criteria include downward, loosened wings, lowered tails, ruffled feathers, and pale combs (5). Within seven days, all hens at both locations were assessed, and stressed-classified hens were indicated with a green avian bracelet on the left leg.

The day after completing hen observation for stress classification, hens classified with stress were randomly assigned to the control or experimental groups at both farms. Hens randomly assigned numbers 1-10 were placed in the control group and those randomly assigned 11-20 were placed in the experimental group. Numbers were written on the hens' green avian bracelet to allow for tracking throughout the experiment. At Farm 1, experimental and control hens were placed into their new respective coops and given seven days to get accustomed to their new surroundings.

During this time, the number of eggs produced per day per group was recorded as well as with observations for hen behavior for each hen. After the seven days of data collection, the experimental group was introduced to seven Free Feathers Foundation Prototype #3 toys, spread evenly throughout the open cage space. Then, data collection paused for three weeks to allow the experimental group hens to interact with the toys. After the three weeks of interaction,

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the number of eggs produced by each hen was counted and behavioral observations were made for each hen over the next seven days.

Statistical Analyses

A paired t-test was used to compare egg production rates before and after the toy interaction period. A p-value 0.05 was taken as significant. All data management and t-tests were done using Microsoft Excel.

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REFERENCES

1. Jacobs, Leonie, and Phillip J. Clauer. "Why Have My Hens Stopped Laying? 5 Factors That Impact Egg Production." *VCE Publications | Virginia Tech*, 12 July 2022.
2. Shini, S., et al. "Effects of Chronic and Repeated Corticosterone Administration in Rearing Chickens on Physiology, the Onset of Lay and Egg Production of Hens." *Physiology & Behavior*, vol. 98, no. 1–2, 4 Aug. 2009, pp. 73–77. https://doi.org/10.1016/j.physbeh.2009.04.012.
3. Urquhart, Kristina Mercedes. "6 Factors That Cause Stress in Chickens." *Hobby Farms | Chickens*, 3 Nov. 2020.
4. Heinsohn, Zachary, et al. "Evaluating the Effects of Feeding a Concentrated Saccharomyces Cerevisiae Fermentation Product on the Performance and Stress Susceptibility of Broiler Chickens." *Poultry*, vol. 3, no. 1, 11 Mar. 2024, pp. 57–65. https://doi.org/10.3390/poultry3010006.
5. Schlegel, Larissa, et al. "How to See Stress in Chickens: On the Way to a Stressed Chicken Scale." *Poultry Science*, vol. 103, no. 8, Aug. 2024, p. 103875. https://doi.org/10.1016/j.psj.2024.103875.
6. APPA [American Pet Product Association]. "The 2021–2022 APPA National Pet Owners Survey." APPA; Stamford, CT, USA: 2022.
7. Macauley, Peter James Luke. "Friends, Food, or "Free Egg Machines"? A Qualitative Study of Chicken Owners' Perceptions of Chickens and Chicken Meat." Oct. 2018.
8. Lara, Lucas, and Marcos Rostagno. "Impact of Heat Stress on Poultry Production." *Animals*, vol. 3, no. 2, 24 Apr. 2013, pp. 356–369. https://doi.org/10.3390/ani3020356.
9. Kromann, Sofie, et al. "Treatment with High-Dose Antidepressants Severely Exacerbates the Pathological Outcome of Experimental Escherichia Coli Infections in Poultry." *PLOS ONE*, vol. 12, no. 10, 2017. https://doi.org/10.1371/journal.pone.0185914
10. Khoshbin, Mohammad Reza et al. "Manganese-methionine chelate improves antioxidant activity, immune system and egg manganese enrichment in the aged laying hens." *Veterinary Medicine and Science,* vol. 9,1 (2023): 217-225. https://doi.org/10.1002/vms3.1008.
11. El-Sabrout, Karim et al. "Feed additives and enrichment materials to reduce chicken stress, maximize productivity, and improve welfare." *Veterinary World,* vol. 17,9 (2024): 2044-2052. https://doi.org/10.14202/vetworld.2024.2044-2052.
12. Moss, Amy F., et al. "Evidence-Based Recommendations for Effective Enrichment to Improve the Welfare of Caged Hens Used for Research and Teaching Purposes." *Poultry*, vol. 3, no. 4, 9 Oct. 2024, pp. 354–363. https://doi.org/10.3390/poultry3040027.
13. Headington, Kenneth et al. "Single cell imaging of the chick retina with adaptive optics." *Current eye research* vol. 36,10 (2011): 947-57. https://doi.org/10.3109/02713683.2011.587934.
14. Ham, A D, and D Osorio. "Colour preferences and colour vision in poultry chicks." *Proceedings. Biological Sciences,* vol. 274,1621 (2007): 1941-8. https://doi.org/10.1098/rspb.2007.0538.
15. Protti-Sánchez, Francesca et al. "In paired preference tests, domestic chicks innately choose the colour green over red, and the shape of a frog over a sphere when both stimuli are green." *Animal Cognition,* vol. 26,6 (2023): 1973-1983. https://doi.org/10.1007/s10071-023-01821-x.
16. Jacobs, L., et al. "Enhancing Their Quality of Life: Environmental Enrichment for Poultry." *Poultry Science*, vol. 102, no. 1, Jan. 2023, p. 102233. https://doi.org/10.1016/j.psj.2022.102233.
17. Staff Team, Newsletter. "Chicken Breed Chart to Help Choose Your Chicken." *College of Agriculture and Natural Resources of Michigan State University.*, 2017.
18. Sharma, Milan K., et al. "Effect of Housing Environment and Hen Strain on Egg Production and Egg Quality as Well as Cloacal and Eggshell Microbiology in Laying Hens." *Poultry Science*, vol. 101, no. 2, Feb. 2022, p. 101595. https://doi.org/10.1016/j.psj.2021.101595.
19. Jacob, Jaqueline P., et al. "Factors Affecting Egg Production in Backyard Chicken Flocks." *Agricultural and Horticultural Enterprises*, no. 1, June 2018, Online Publication #PS-35.
20. Butcher, J.D., et al. "Common Poultry Diseases." *Agricultural and Horticultural Enterprises*, no. 1, Feb. 2019, Online Publication #PS-47.