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RESEARCH ARTICLE

Effects of Shower-Based Environmental Enrichment During a 35-Day Grow-Out Period on Production Performance, Stress Physiology, Fear Responses and Gut Health in Pekin Ducks

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Abstract

Background and Objective: Pekin ducks exhibit a strong behavioral motivation for access to open water; however, commercial production systems in the United States typically provide only nipple drinkers. Overhead shower enrichment (SE) represents a potential alternative to ground-level water sources, yet its effects on production performance, physiological stress, behavioral fear responses and gut health remain incompletely characterized. The present study aimed to evaluate the effects of automated overhead shower enrichment on growth performance, physiological stress indicators, behavioral fear responses and ileal histomorphology in commercial Pekin ducks reared under standard management conditions in the United States.

Materials and Methods: Two replicated trials were conducted using a total of 640 Pekin ducklings (day 0-35). Birds were allocated to 16 pens per treatment, with 20 ducks per pen and assigned to either a shower enrichment group (SE; automated overhead sprinkler provided from day 7 to 35 at 30 min intervals for 10 h/day) or a nipple-drinker control group (CON). At day 35, outcomes assessed included growth performance (body weight and feed conversion ratio), physiological stress indicators (plasma corticosterone concentration, heterophil-to-lymphocyte ratio and bilateral asymmetry), behavioral fear responses (inversion and tonic immobility tests) and ileal histomorphology (villus height, crypt depth and villus height to crypt depth ratio).

Results: Body weight (2.73 vs. 2.67 kg, $p = 0.12$) and feed conversion ratio (1.525 vs. 1.532, $p = 0.71$) did not differ between the SE and CON groups. Similarly, physiological stress indicators, including heterophil-to-lymphocyte ratio (0.52 vs. 0.56, $p = 0.59$), composite asymmetry (1.23 vs. 1.25, $p = 0.78$) and plasma corticosterone concentration (10,814 vs. 10,653 pg/mL, $p = 0.93$), were not significantly affected by treatment. Behavioral fear responses were also comparable between groups ($P > 0.05$). Ileal villus height and the villus height to crypt depth ratio did not differ between treatments; however, ducks in the SE group exhibited significantly greater crypt depth than those in the CON group (132 vs. 86 µm, $p = 0.007$).

Conclusion: Shower enrichment did not adversely affect growth performance, physiological stress responses, or behavioral fear indicators in commercial Pekin ducks. The observed increase in ileal crypt depth, in the absence of changes in other histomorphological parameters, warrants further investigation. Overall, these findings indicate that overhead shower enrichment represents a welfare-enhancing, production-neutral strategy that is compatible with voluntary open-water certification standards.

INTRODUCTION

Domestic Pekin ducks (*Anas platyrhynchos* f. domestica) are the primary species used for commercial meat production in the United States, with more than 200 million birds slaughtered annually across the United States and the European Union. Pekin ducks are derived from the wild Mallard and retain the behavioral repertoire characteristic of semi-aquatic waterfowl, including wet preening, bathing, bill-dabbling and head-dipping. These behaviors are essential for maintaining feather water repellency and for the effective cleaning of the eyes and nostrils. Despite these inherent behavioral requirements, conventional commercial housing systems in the United States rely exclusively on nipple or pin-metered drinker lines, which adequately meet hydration needs but do not allow head immersion or surface wetting necessary for natural maintenance behaviors.

Substantial evidence indicates that restriction to nipple drinkers compromises duck hygiene and welfare. Ducks deprived of access to open water consistently exhibit poorer eye and nostril cleanliness, as well as increased plumage soiling, compared with birds provided access to troughs, baths, or overhead water sources. Jones *et al.*[1] reported that ducks reared exclusively with nipple drinkers were the only group to exhibit a high prevalence of dirty eyes (45.8%) and blocked nostrils (62.5%) at six weeks of age. These birds also demonstrated compensatory "rebound" bathing behavior following delayed access to water, suggesting prior behavioral deprivation. Similarly, gait scores have been reported to be inferior in ducks restricted to narrow-lip bell drinkers compared with those provided trough or bath access[2].

Water restriction has also been associated with elevated physiological stress responses in ducks. Harvey *et al.*[3] demonstrated that 24 hrs deprivation of food or water significantly increased plasma corticosterone (CORT) concentrations, supporting its use as a biomarker of stress in this species. Further studies have shown that water restriction in Muscovy ducks is associated with increased serum CORT levels and a higher incidence of feather pecking behavior[4]. In Pekin ducks, the heterophil-to-lymphocyte (H:L) ratio and composite asymmetry of bilateral morphological traits are well-established indicators of chronic physiological stress[5,6], while tonic immobility (TI) and inversion tests are widely used to assess behavioral fear responses[7,8].

From a practical perspective, the implementation of ground-level open water systems, such as troughs and baths, presents significant management challenges. These systems are associated with increased litter moisture, elevated ammonia levels and greater microbial contamination and under certain conditions have been linked to higher mortality rates and an increased incidence of footpad dermatitis. Overhead shower and misting systems have emerged as a feasible alternative, providing water contact without substantially compromising litter quality. Experimental studies by Jones *et al.*[1] and Waitt *et al.*[9] demonstrated that overhead showers are functionally comparable to baths and troughs in meeting ducks' motivation to bathe, as evidenced by behavioral time budgets and the absence of rebound behaviors. In a commercial-scale study, Campbell *et al.*[10] further reported that misting applied for one hour per day did not increase mortality and stimulated wet preening behavior in growing Pekin ducks. Nevertheless, the effects of repeated daily overhead shower enrichment on a comprehensive range of outcomes, including production performance, stress physiology, fear responses and gut health, have not been fully elucidated under standard U.S. commercial conditions.

Increasing regulatory and market-driven demands for improved welfare in duck production have intensified interest in open water provision. Voluntary certification programs, including RSPCA Assured, Humane Choice, Animal Welfare Approved and Global Animal Partnership, require the inclusion of open water access in production systems. Accordingly, evaluating whether overhead shower enrichment can satisfy welfare requirements without adversely affecting production efficiency or bird health is of considerable practical importance. Therefore, the objective of the present study was to assess the effects of automated overhead shower enrichment on growth performance (body weight gain, feed conversion ratio), physiological stress indicators (plasma corticosterone, H:L ratio, bilateral asymmetry), behavioral fear responses (inversion and tonic immobility) and ileal histomorphology in commercial Pekin ducks reared under standard U.S. management conditions.

MATERIALS AND METHODS

Animals, housing and experimental design: The study consisted of two replicate trials involving a total of 640 day-old Pekin ducklings obtained from Maple Leaf Farms Inc. (Leesburg, IN, USA). Each trial included two treatments with four replicates per treatment. All experimental procedures were approved by the Institutional Animal Care and Use Committee [IACUC 2019-0134].

Birds were housed in two tunnel-ventilated rooms, each measuring 6.1 m×9.1 m. Each room contained eight raised-floor pens (0.9 m×3.6 m×0.6 m) fitted with black slatted plastic flooring with 2.5 cm gaps (Part #13501, Double L Group, LLC, Deyersville, IA, USA). Each pen was divided by a

central wooden partition featuring a 30.5 cm×61.0 cm opening, allowing unrestricted movement between the two sections. One section (Side A) was equipped with a single tube feeder and three nipple drinkers per pen, both of which were adjusted according to bird height throughout the study. The second section (Side B) was designated for the installation of Shower Enrichment Devices (SED) in treatment pens and remained unmodified in control pens.

At placement, all ducklings were individually weighed and randomly allocated to pens at a stocking density of 20 birds per pen (n = 32 pens total). Birds were maintained under a 24L:0D lighting schedule at 20 lux during days 0-1, followed by a 16L:8D photoperiod thereafter. Light intensity was reduced to 5 lux from day 10 through day 35. Each room was illuminated by six incandescent bulbs mounted at a height of 3 m and controlled by a centralized dimmer and timer system. To minimize potential pen location effects between trials, SEDs were removed from their original positions and reassigned to adjacent pens prior to the initiation of Trial 2.

Shower enrichment treatment: Birds were randomly assigned to one of two experimental treatments: Shower enrichment (SE) or a nipple-drinker control (CON). Each SE pen was fitted with a single SED consisting of a rotary lawn sprinkler (Model #8802, Yardsmith®, USA) connected to an automated irrigation system (Fig. 1). Devices were centrally mounted in Side B at a height of 0.6 m above the pen floor. Within each room, the four SEDs were operated via a common irrigation unit and both units were programmed identically.

Shower enrichment was applied from day 7 through day 35, with SEDs activated at 30-minute intervals over a 10-hour daily period (09:00-21:00). No shower exposure was provided during days 0-6 to allow birds to acclimate to the housing environment. Control pens did not receive any additional enrichment beyond standard nipple drinkers.

Diets: All experimental diets were formulated and manufactured at the Texas A&M University feed mill. A standard commercial starter diet was provided *ad libitum* from day 0 to day 14, followed by a grower diet from day 15 to day 35. Feed allocations were recorded prior to distribution to each pen and residual feed was weighed at the end of each feeding phase to enable accurate determination of total feed intake per pen.

Growth performance: Pen-level Body Weights (BW) were recorded at placement (day 0) and at the end of the grow-out period (day 35). Body weight gain (BWG, kg) was calculated as the difference between day 35 and day 0 pen weights. Feed conversion ratio (FCR) was calculated as the ratio of total feed intake to total BWG on a per-pen basis and was adjusted for mortality. Mortalities and culls were recorded daily, with each bird individually weighed and documented throughout the study period.

Stress measures

Plasma corticosterone and heterophil-to-lymphocyte ratio: On day 35, blood samples were collected from the brachial vein of 20 birds per treatment (N = 80 total) between 08:00 and 09:00 hr. To minimize handling-induced stress and ensure that sampling was completed within 45 sec of initial contact, multiple trained personnel conducted collections simultaneously, as corticosterone (CORT) concentrations in domestic ducks are known to increase within approximately

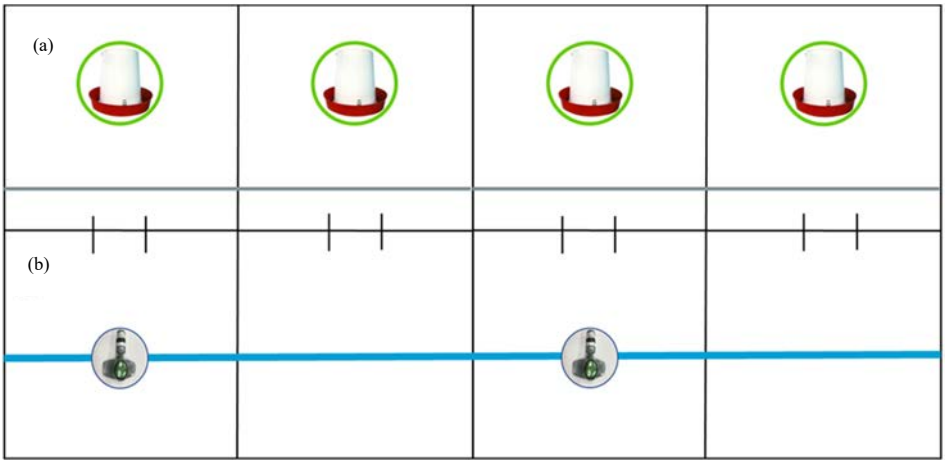

Fig. 1: Pen layout with Side A having feeders and water lines and Side B having either shower or no shower with a 30.5 cm (w) × 61.0 cm (h) opening between the sides

1 min of handling. Blood samples were collected into plasma separation gel and lithium heparin vacutainer tubes (BD 368056, BD, Franklin Lakes, NJ), maintained on ice and subsequently centrifuged (Eppendorf 5804, Eppendorf North America, Hauppauge, NY) at 4,000 RPM for 15 min. Plasma was then harvested, transferred to 2 mL microcentrifuge tubes and stored at -19°C until analysis.

Plasma CORT concentrations were quantified using a commercial ELISA kit (Enzo Life Sciences, ADI-901-097, Farmingdale, NY), with both inter- and intra-assay coefficients of variation maintained below 5%. Corticosterone is the primary glucocorticoid used as a validated biomarker of stress in domestic ducks and is known to increase in response to both acute and chronic stressors.

Simultaneously, a drop of whole blood from each sampled bird was smeared onto a glass slide and stained using a commercial hematology staining kit (Cat# 25034, Polysciences Inc., Warrington, PA). Differential leukocyte counts were performed under a 40× oil-immersion objective (Omax DCE-2, Kent, WA) using a manual tally counter, with counts continuing until 100 leukocytes were enumerated per slide. The heterophil-to-lymphocyte (H:L) ratio was subsequently calculated and used as an indicator of chronic physiological stress, with elevated ratios reflecting prolonged activation of the hypothalamic-pituitary-adrenal axis and associated shifts in immune function.

Physical asymmetry of bilateral traits: Composite bilateral asymmetry was assessed on day 35 in a random subsample of 60 birds per treatment (N = 240) using calibrated digital calipers (Craftsman IP54, Sears Holdings, Hoffman Estates, IL). Three paired morphological traits were measured, including Middle Toe Length (MTL), metatarsal width (MW) and metatarsal length (ML). A composite asymmetry index was calculated for each individual according to the method described by Huth and Archer[5]: (|L−R|MTL+|L−R|MW+|L−R|ML) / 3. Higher values of this index are indicative of increased developmental instability and are interpreted as reflecting cumulative exposure to chronic stress.

Fear response

Inversion test: A random sample of 60 ducks per treatment (N = 240) was subjected to inversion testing at five weeks of age, following the methodology described by Archer and Mench[7]. Each bird was gently restrained by the legs, inverted into a dorsal recumbent position and held for up to 30 sec or until wing flapping ceased. All trials were recorded using a digital video camera (Canon ZR900, Melville, NY; 24 frames/s) and behavioral parameters were subsequently quantified via frame-by-frame analysis. The variables measured included total wing flap count, duration of flapping (s) and flapping intensity (flaps/s). This test provides an index of acute fear responsiveness based on the magnitude of escape-related motor activity elicited by a standardized aversive stimulus.

Tonic immobility test: A separate cohort of 60 birds per treatment, not previously subjected to inversion testing (N = 240), was evaluated for tonic immobility (TI) during week 5 using a protocol adapted from Archer[8]. Each bird was placed in a supine position within a black cloth-lined, U-shaped wooden cradle and gentle pressure was applied to the thoracic region for 30 sec. Timing commenced immediately upon release of restraint. Induction was considered successful if the bird remained immobile for at least 10 sec without escape attempts. For successfully induced birds, the following parameters were recorded: latency to first head movement (s), latency to righting (s) and the number of induction attempts required. A maximum of three induction attempts per bird was allowed; individuals that failed to enter TI were assigned a righting latency of 0 sec. The duration of TI is widely used as an indicator of fearfulness, with longer durations reflecting a more pronounced anti-predator response.

Gut health, ileal histomorphology: On day 35, 20 birds per treatment (two per pen) were randomly selected and humanely euthanized using a pneumatic captive bolt device (Zephyr-EXL, Schuyler, NE). A 3 cm segment of the ileum was excised from the midpoint between the ileocecal junction and Meckel's diverticulum, rinsed with phosphate-buffered saline and fixed in 30 mL of 10% neutral-buffered formalin at room temperature. Samples were submitted to StageBio Laboratories (Mount Jackson, VA) for routine histological processing, including paraffin embedding, sectioning and staining with Periodic Acid–Schiff (PAS) and Alcian Blue (AB). Histological images were captured at 4× magnification using a Nikon Eclipse Ci-L microscope (Nikon Corporation, Tokyo, Japan). For each sample, six intact villi were selected for morphometric analysis using Elements software. Measured parameters included villus height (VH; from the tip of the villus to the villus–crypt junction), crypt depth (CD; from the base of the crypt to the muscularis mucosae) and the villus height to crypt depth (VH:CD) ratio.

Statistical analysis: Data were analyzed using one-way analysis of variance (ANOVA) to evaluate treatment effects on body weight (BW), Feed Conversion Ratio (FCR), mortality, plasma corticosterone concentration, heterophil-to-lymphocyte (H:L) ratio, inversion test variables, tonic

immobility parameters and ileal histomorphology. The Kruskal-Wallis test was applied to assess treatment effects on the number of attempts required to induce tonic immobility. Assumptions of the general linear model were evaluated using Levene's test for homogeneity of variance and the Shapiro-Wilk test for normality. When significant effects were detected, means were separated using Fisher's least significant difference (LSD) test. All assumptions were satisfied without the need for data transformation. Statistical analyses were conducted using Minitab version 17.1.0. Data are presented as means±pooled standard error of the mean (SEM) and statistical significance was defined at $p<0.05$.

RESULTS

Growth performance: No significant differences were observed between SE and CON ducks in body weight at day 35 (CON: 2.67±0.02 kg, SE: 2.73±0.02 kg, $p = 0.12$) or feed conversion ratio (CON: 1.532±0.01; SE: 1.525 ± 0.01; $p = 0.71$; Table 1). Total flock mortality did not differ between treatments across both trials ($p>0.05$).

Stress measures: Plasma corticosterone (CORT) concentrations at day 35 were not significantly different between SE and CON groups (CON: 10,653 ± 916 pg/mL; SE: 10,814±916 pg/mL, $p = 0.93$; Table 1). Similarly, heterophil-to-lymphocyte (H:L) ratios did not differ between treatments (CON: 0.56±0.04; SE: 0.52±0.04, $p = 0.59$). Composite asymmetry scores were also comparable between SE and CON ducks (CON: 1.25±0.04, SE: 1.23±0.04, $p = 0.78$; Table 1).

Fear response: Measures obtained from the inversion test, including number of wing flaps (CON: 5.9±0.32, SE: 5.3±0.32. $p = 0.34$), duration of wing flapping (CON: 6.0±0.28 sec, SE, 5.8±0.28 sec, $p = 0.71$) and flapping intensity (CON: 1.1±0.03 flaps/s, SE: 1.0±0.03 flaps/s, $p = 0.17$), did not differ significantly between treatments at week 5 (Table 1). Likewise, tonic immobility parameters, including latency to first head movement (CON: 109.7±10.4 sec, SE: 116.4±10.4 sec, $p = 0.75$), latency to righting (CON: 159.5±12.1 sec, SE: 170.2±12.1 sec, $p = 0.66$) and number of induction attempts (CON: 1.7±0.1, SE: 1.6±0.1, $p = 0.29$), were not significantly affected by treatment (Table 1).

Ileal histomorphology: Ileal villus height did not differ between SE and CON groups (CON: 408±22 µm, SE: 419±22 µm, $p = 0.70$; Table 1). In contrast, ileal crypt depth was significantly greater in SE ducks compared with CON ducks (CON: 86±10 µm, SE: 132±10 µm, $p = 0.007$). The villus height to crypt depth (VH:CD) ratio was not significantly different between treatments (CON: 4.89±0.18, SE: 4.58±0.18; $p = 0.36$).

DISCUSSION

The primary finding of this study is that automated overhead shower enrichment administered from day 7 to day 35 did not adversely affect body weight gain, feed conversion ratio, physiological stress indicators, behavioral fear responses, or ileal histomorphology in commercial Pekin ducks. These results support the growing body of evidence indicating that overhead shower or misting systems represent a commercially feasible strategy for enhancing duck welfare without incurring measurable production or health penalties.

The absence of treatment effects on growth performance (BWG and FCR) is consistent with previous studies evaluating water-based enrichment. O'Driscoll and Broom[11] reported lower body weights at day 43 in ducks provided only narrow-

Table 1: Effect of shower enrichment on production performance, physiological stress, fear responses and ileal histomorphology of Pekin ducks at d 35 (LSM±SEM)

Measure	CON	SE	SEM	p-value
day 35 body weight (kg)	2.670	2.730	0.02	0.120
FCR	1.532	1.525	0.01	0.710
Time to first head movement during Tonic Immobility (s)	109.700	116.400	10.40	0.750
Time to right during Tonic Immobility (s)	159.500	170.200	12.10	0.660
No. of attempts to induce Tonic Immobility	1.700	1.600	0.10	0.290
No. of flaps during Inversion	5.900	5.300	0.32	0.340
Duration of flapping during Inversion (s)	6.000	5.800	0.28	0.710
Intensity of Flapping during Inversion (flaps/s)	1.100	1.000	0.03	0.170
Plasma Corticosterone (pg/ml)	10653.000	10814.000	916.00	0.930
Heterophil to lymphocyte Ratio	0.560	0.520	0.04	0.590
Composite asymmetry Score	1.250	1.230	0.04	0.780
Ileal Villi Height (um)	408.000	419.000	22.00	0.700
Ileal crypt depth (um)	86.000	132.000	10.00	0.007
Villi height to Crypt depth ratio	4.890	4.580	0.18	0.360

CON: Control (nipple drinkers only), SE: Shower enrichment, SEM: Standard error of the mean, TI: Tonic immobility, VH: Villus height, CD: Crypt depth, Data pooled across two trials. $p < 0.05$

lip bell drinkers compared with those given access to troughs or baths, suggesting that open water access may confer modest growth advantages. Similarly, Jones and Dawkins[2] observed higher body weights in ducks provided with open water relative to those restricted to narrow-lip bell drinkers by day 43. Schober *et al.*[12] also demonstrated that ducks with access to open-water Pekino drinkers and preening cups exhibited greater body weights than nipple-line controls. The lack of a growth response in the present study likely reflects the adequacy of nutrient and water intake provided by nipple drinkers, with shower enrichment functioning primarily as a behavioral resource rather than a source of hydration. This interpretation is further supported by findings from Campbell *et al.*[10], who reported no difference in mortality between misted and non-misted commercial flocks, suggesting that overhead delivery systems mitigate the increased litter moisture and associated mortality risks linked to ground-level water sources, as described by Schenk *et al.*[13]. Plasma corticosterone (CORT) concentrations did not differ between SE and CON treatments, indicating that repeated daily exposure to shower enrichment did not act as a chronic stressor, nor did it markedly reduce baseline stress levels. This outcome is biologically plausible, given that ducks in the CON treatment were housed on raised slatted flooring with consistent access to nipple drinkers, conditions that likely represent a relatively low-stress environment compared with litter-based systems or conditions involving water restriction. Fairhurst *et al.*[14] demonstrated that exposure to novel enrichment can induce transient elevations in corticosterone, followed by habituation with continued exposure. In the present study, the predictable and repeated activation of the shower system from day 7 onward likely facilitated habituation, thereby preventing sustained increases in CORT concentrations. Furthermore, the absence of treatment effects on heterophil-to-lymphocyte (H:L) ratio and composite bilateral asymmetry, both of which reflect cumulative physiological stress, supports the conclusion that prolonged exposure to shower enrichment did not induce chronic stress.

The lack of treatment effects on tonic immobility (TI) latency and inversion test parameters indicates that shower enrichment did not influence fear responsiveness in Pekin ducks over the 5-weeks rearing period. This finding has practical relevance for commercial production, as elevated fearfulness and associated smothering events represent recognized risks to both welfare and mortality in Pekin ducks. The absence of detectable effects may suggest that, although shower enrichment provides a novel sensory stimulus, it does not introduce sufficient environmental or social complexity to elicit measurable habituation of fear responses. Alternatively, fear-related behaviors in Pekin ducks may be relatively insensitive to water-based enrichment, with variation more strongly influenced by genetic and broader environmental factors, as proposed by Arnaud *et al.* (cited in Chen *et al.*[15]).

Analysis of ileal histomorphology yielded a distinct outcome. While villus height and the villus height to crypt depth (VH:CD) ratio did not differ between treatments ($p = 0.70$ and $p = 0.36$, respectively), ducks in the SE group exhibited significantly greater ileal crypt depth than those in the CON group (132 vs. 86 µm, $p = 0.007$). Crypt depth is commonly interpreted as an indicator of enterocyte proliferative activity, with increased depth reflecting enhanced mucosal turnover. This may represent either an adaptive response to altered luminal conditions or a mild stimulatory or inflammatory process. Interpretation of this isolated increase is limited by the absence of concurrent changes in villus height or growth performance. One possible explanation is that repeated exposure to overhead water altered the microenvironment within the pen, potentially influencing microbial or moisture dynamics in a manner that stimulated mucosal renewal without impairing absorptive capacity, as evidenced by the unchanged VH:CD ratio and growth metrics. Alternatively, increased behavioral activity associated with shower use may have affected intestinal motility or digesta passage rate. These histomorphological parameters are sensitive to dietary, microbial and immunological influences, including pathogen exposure and cytokine-mediated responses. Given that neither VH:CD ratio nor body weight was affected, the observed increase in crypt depth does not appear to have compromised overall intestinal function. Nevertheless, further investigation incorporating mucosal immune markers and microbiome analysis is warranted to determine whether shower enrichment induces consistent and biologically meaningful alterations in gut physiology. Importantly, because overhead showers do not directly contact feed or create persistently wet substrates, the potential biosecurity risks associated with pathogen proliferation in contaminated standing water, as observed in ground-level systems, are unlikely to be activated under this delivery method.

These findings should be interpreted within the context of the broader literature. Welfare indicators not evaluated in the present study, including eye and nostril cleanliness, feather condition and wet preening behavior, have been consistently shown to improve with water enrichment that allows head immersion. The overhead shower system employed in this study delivered water from above but did not

provide a standing water surface suitable for head-dipping. Future research should therefore assess whether such systems adequately facilitate full bill and head immersion and should include direct measurement of hygiene-related outcomes, which are among the most robust indicators of welfare improvement in ducks.

From a commercial standpoint, overhead shower enrichment addresses key limitations associated with traditional open water systems, particularly increased litter moisture, elevated bacterial load and associated health risks. Schenk *et al.*[13] reported increased mortality in ducks provided with water troughs compared with nipple drinkers under U.S. production conditions, while Lowman *et al.*[16] observed reduced egg production and increased footpad lesions in breeder ducks housed with trough systems. The absence of such adverse effects in the present study suggests that overhead shower enrichment represents a practical and scalable alternative, with potential applicability in production systems seeking to meet voluntary certification standards that require open water provision.

CONCLUSION

Automated overhead shower enrichment applied from day 7 to day 35 did not significantly influence body weight gain, feed conversion ratio, plasma corticosterone concentrations, heterophil-to-lymphocyte ratio, bilateral morphological asymmetry, tonic immobility, inversion-based fear responses, villus height, or the villus height to crypt depth (VH:CD) ratio in commercial Pekin ducks relative to a nipple-drinker control. Ducks exposed to shower enrichment exhibited a significant increase in ileal crypt depth compared with control birds ($p = 0.007$); however, this change was not associated with reductions in growth performance or indicators of intestinal absorptive capacity. These findings demonstrate that overhead shower enrichment can be incorporated into commercial grow-out systems without adversely affecting production efficiency or inducing measurable physiological stress. When considered alongside previous evidence indicating that such systems promote wet preening behavior and are behaviorally preferred over conventional nipple drinkers, the present results support the use of overhead shower enrichment as a welfare-enhancing, production-neutral management strategy. Accordingly, producers seeking certification under welfare standards that require open water provision may consider overhead shower systems as a practical and biosecure alternative. Future research should further investigate the effects of shower enrichment on eye and nostril hygiene, feather condition, litter quality and optimization of shower delivery protocols to refine best-practice recommendations.

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