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Behavior and welfare impacts of water provision via misting in commercial Pekin ducks

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Abstract

Ducks will access water to maintain feather condition and exhibit natural water-related behaviors such as wet preening. Providing water to ducks commercially is challenging as it may reduce litter and air quality leading to higher duck mortality or illness. This research aimed to measure the behavioral and welfare impacts of water provision via a misting system for commercial Pekin grower ducks in Victoria, Australia. Seven grower flocks were observed (four misted and three nonmisted in open-sided sheds) during May and November 2021. From 26 until 33 d of age, treatment ducks were provided 1 h of misting with shed curtains closed in both treatment and control sheds. At the start and end of the misting application period, external health and welfare measures were taken directly on the ducks via transect walks throughout each shed and catch-and-inspect observations on a sample of 150 ducks from each shed. Video recordings were also made of the misted and nonmisted ducks for 3 h representing time periods prior to, during, and after the 1-h misting across all sheds for all 8 d of the treatment period. Observations were made of all behavior that ducks exhibited at 10-min scan sample intervals across four cameras per shed, totaling 4,198 scans across the seven sheds. General linear mixed models showed the misting application predominantly had impacts on the patterns of behavioral change across the treatment time periods between the misted and nonmisted ducks rather than increasing or decreasing the overall expression of specific behaviors (interaction terms all $P \leq 0.003$). The misted ducks increased drinking, tail wagging, and walking, and reduced preening, rooting litter, sitting, and stretching during misting relative to what they showed prior. The nonmisted ducks showed less sitting and more panting during misting relative to prior. Pearson's Chi-square tests showed some differences between the treatment groups in feather cleanliness on the back and wings (both $P < 0.0001$), likely resulting from pre-existing differences between sheds in blood from pin feathers. Most welfare indicators showed no positive or negative effect of the misting treatment. These results indicate overhead misting does affect duck behavior to some degree without compromising their welfare, but further research with larger water droplet sizes resulting in greater accumulation of surface water or extended durations of misting may lead to greater effects.

Lay summary

Ducks use bathing water for wet preening and feather maintenance. Commercially, it is challenging to provide clean bathing water without compromising litter quality and duck health. Overhead misting may be a mode of water delivery that will wet the ducks' bodies with continuously clean water. This study compared seven grower flocks of Pekin ducks (four misted and three nonmisted treatment flocks) in open-sided sheds during May and November 2021 in Australia. From 26 until 33 d of age, treatment ducks were provided 1 h of misting with shed curtains closed in both treatment and control sheds. External welfare measures were taken directly on the ducks at 26 and 33 d of age. Daily video recordings were made to observe if behaviors differed before, during, or after the 1 h of misting in both treatment and control sheds. Results showed the misting application predominantly affected the way behaviors changed across time between the misted and nonmisted ducks rather than increasing or decreasing the overall expression of specific behaviors. The differences may have in part been related to the curtain closure. Most welfare indicators showed no positive or negative effect of the misting treatment. Larger water droplet sizes may have greater effects on duck behavior.

Key words: blood, feathers, health, poultry, preening

Abbreviations: CAI, catch-and-inspect; TW, transect walks; GLMM, general linear mixed model; REML, restricted maximum likelihood; LSM, least squares means

Introduction

Commercial ducks are domesticated birds that encompass several different species/breeds and are raised for multiple uses including feathers, eggs, foie gras, and meat (Karcher and Mench, 2018). The most common ducks used for commercial meat production are Pekin, Muscovy, and Mule (hybrid between the Pekin and Muscovy) with varying prevalence depending on the global region (Karcher and Mench, 2018; Babington and Campbell, 2022). Similar to chicken meat production, grower meat ducks have fast growth rates and are slaughtered around 5 to 6 wk of age depending on the strain. Across regions, grower ducks are housed in different types of floor-based systems with a combination of indoor and outdoor areas, or exclusively indoor with enclosed or open-air ventilation (Jalaludeen and Churchil, 2022). Within indoor housing, the birds are typically provided litter or raised plastic/wire flooring, nipple or bell drinkers, and food (Karcher and Mench, 2018). However, domesticated ducks are

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semiaquatic waterfowl and a major challenge within the industry is how to safely provide bathing/surface water (Babington and Campbell, 2022). With global drives to improve the welfare of livestock animals, surface water provision in commercial grower duck production systems is a key issue that remains controversial because of the practical difficulties of proving a water resource whilst maintaining animal health outcomes.

When water is available, domesticated ducks will engage in water-related behaviors such as swimming, dabbling, and wet preening (Jones et al., 2009; Waitt et al., 2009; Liste et al., 2012a). This preening is important for maintaining feather condition and water that allows head dipping is important for maintaining clean eyes and nostrils (Jones et al., 2009; O'Driscoll and Broom, 2011; Liste et al., 2012b). However, Schenk et al. (2016) identified negative effects of water troughs on feather and eye conditions. There is some experimental evidence that Pekin ducks are motivated to access bathing water. Cooper et al. (2002) used barriers of different heights to show that ducks between 4 and 8 wk of age "worked" harder to access troughs over nipple drinkers, Plasson bell drinkers, or deeper turkey bell drinkers. Similarly, an assessment of rebound behavior following deprivation showed ducks previously provided access to only nipple drinkers spent more than double the time bathing compared to ducks who had previously had access to bathing water (Jones et al., 2009).

Providing water to ducks on commercial farms is logistically challenging and may have negative consequences for bird health. Bodies of water in commercial settings can become areas for bacterial contamination (Liste et al., 2013) and contaminated troughs (provided both as bathing and drinking water) have resulted in higher duck mortality relative to when water is only provided via nipple drinkers (Schenk et al., 2016). Increased amounts of water can lead to more wet litter which has significant welfare implications for foot and leg health (Jones and Dawkins, 2010a; Schenk et al., 2016). Ducks may use the water less when it becomes contaminated (Liste et al., 2012a) and frequent water turnover to maintain water quality could have substantial environmental impacts through water usage and wastage (Liste et al., 2013; Schenk et al., 2016) compromising commercial system sustainability.

Water provision in commercial grower systems may improve feather condition, eye and nostril health, behavioral repertoire, and it may facilitate positive water-related experiences for ducks, but to date, there is no validated method of bathing water delivery that does not compromise bird health and/or system sustainability (see Babington and Campbell, 2022, for a review on water provision for commercial ducks). Thus, current international duck farming regulations across various regions do not dictate bathing water provision (Poultry S&Gs Drafting Group, 2016) with the U.K. standards recommending water for head dipping but only if it can be provided in a safe manner (DEFRA, 2004). Some voluntary animal welfare certification programs aimed at providing higher welfare standards for ducks require their participating producers to provide ducks with a water source that enables ducks to bath and/or immerse their heads and wet preen, such as American Humane Certified™ in the United States (American Humane Association, 2019) and the Royal Society for the Prevention of Cruelty to Animals in the United Kingdom (RSPCA, 2015).

Previous comparisons of varying types of water sources in an experimental setting, including small ponds, troughs, showers, or water nipples, found similar preferences and usage by ducks for ponds, troughs, and showers (Jones et al., 2009; Waitt et al., 2009). When comparing commercial barns where ducks had access to one type of water resource (trough, Plasson bell drinker, or water nipples), a greater proportion of the maximum number of ducks able to use the water resource was present at troughs, then large Plasson bell drinkers, and then water nipples (Jones and Dawkins, 2010b). Some duck-specific waterlines with larger cup drinkers that enable the ducks to dip their heads and extract water for preening purposes have been developed (Klambeck et al., 2015), but testing on commercial farms within Australia found significant negative effects on litter quality and substantial increases in water usage (DLMC, 2021, personal communication). Water provision via misting application from the above may be a method of delivery that enables the birds to become surface wet, which could facilitate wet preening and keep eyes and nostrils clean while having minimal negative impacts on duck health and litter quality. Overhead sprinklers for surface wetting of commercial broiler chickens for heat mitigation have been shown to be effective in alleviating heat stress to improve performance while utilizing significantly less water than cooling pads (Liang et al., 2020).

To date, there is limited research in commercial settings on effective methods for delivering water to grower ducks that facilitate water-related behaviors. Thus, the current study was designed to assess the impact of water provision via misting on behavior and external welfare measures in commercial Pekin grower ducks. The ducks with water provision were predicted to show more preening and improved feather, nostril, and eye cleanliness without other compromises to their welfare.

Methods

Ethical statement

This research was approved by the CSIRO Wildlife, Livestock and Laboratory Animal AEC (Approval number: 2020-32).

Commercial sheds and setup

The research was carried out on a single commercial Pekin duck (Cherry Valley strain) grower farm located in Victoria, Australia, with Cohort 1 tested in May 2021 and Cohort 2 tested in November 2021. The property housed four standalone neighboring open-sided sheds (150 m L × 15 m W) with curtains that could be raised up and down for ventilation purposes, and provided both artificial fluorescent and natural lighting. Each floor-based shed contained three rows of nipple drinkers and two rows of pan feeders along its length with wood shavings as litter. When the ducklings were placed, there was a thin spread (~3 cm deep) of shavings on the floor. Throughout the growth cycle, the litter was managed daily based on visual need which included turning the litter and/or topping it up. Thus, litter continued to increase in depth as the ducks aged until it reached over 10 cm in depth during the study period. No experimental restrictions were placed on litter management as maintenance of litter quality was left to the experienced farm staff. There were no reported substantial differences by farm management staff in how they attended to the litter among sheds. The sheds were exposed to ambient outdoor temperatures which were (mean ± SEM) 20.08 ± 0.16 °C across the study period for Cohort 1 and 27.57 ± 0.22 °C for Cohort 2 as measured by temperature loggers (Tinytag Plus 2, TGP-4500; Gemini Data Loggers Ltd, West Sussex, United Kingdom) installed on the outside of two sheds, recording at 15-min intervals during the hours of observation only: 11:00 to 14:00 daily. The mean relative outdoor humidity during the treatment hours was 54.6% ± 1.0% for Cohort 1 and 44.14% ± 1.3% for Cohort 2.

Prior to the placement of ducklings, four cameras were installed in each shed to capture a portion of the shed. Two cameras (Hikvision DS-2CD2355FWD-I2 CCTV 6MP Turret cameras) were installed at 1 m height off the ground on one side (15 and 22.5 m from the shed entrance), with two cameras installed directly opposite on the other side of the shed. These cameras captured a representative sample of the total flock within each shed with the litter area and a drinker line visible in the recordings. Each set of four cameras was connected to an NVR system (Hikvision DS-7608NI-I2-8P CCTV NVR Recorder) located in the entrance room of each shed. Three temperature and humidity loggers (Tinytag Plus 2, TGP-4500) were attached to one of the feeder lines in the center of each shed at bird height and recorded ambient indoor conditions at 15-min intervals during the observation period. Video was recorded for a 3-h period daily from 26 to 33 d of age. For Cohort 1 on day 0, 15,240 to 16,680 ducklings were placed into each of the four sheds but in a staggered method, so that sheds A and B (misted/nonmisted, respectively) were placed 2 d earlier than sheds C and D (misted/nonmisted, respectively). For Cohort 2, 12,540 ducklings were placed into each of three sheds in a staggered method, so that sheds A and B (misted/nonmisted, respectively) were placed 1 d earlier than shed C (misted). Shed D was not used in the second cohort as the farm staff were placing fewer birds to meet reduced demand resulting from COVID-19 (see Table S1 for all duck numbers and shed treatments). Bird density for Cohorts 1 and 2 were approximately 7 and 5.5 duck per m^2 respectively. The ducks were managed by experienced farm staff as per standard farm husbandry protocols.

Experimental protocol and data collection

Welfare scoring

The same experimental protocols were applied for both Cohort 1 and Cohort 2 with a total of seven flocks included in the experiment (four misted and three nonmisted treatment sheds). Each standalone shed was either misted or nonmisted with no drift between sheds due to the distance they were separated on the property. On day 26 following placement, the first set of welfare scoring via the catch-and-inspect method (Abdelfattah et al., 2020) was carried out for shed A. Shed B was assessed on the morning of day 27 due to logistical time constraints during day 26 delaying the welfare scoring, but henceforth all sheds were assessed on days 26 and 33. A sample of approximately 150 birds in total was corralled into a corner of the shed but was captured in smaller groups of approximately 40 to 50 birds to minimize potential smothering and stress during handling. During the first two scoring sessions, 200 ducks were captured until it was decided this number was too large to logistically complete within the sampling time frame, and on some occasions, a few extra ducks were scored if they had already been corralled. Each bird was individually weighed and scored by one of three observers following a scoring protocol based on that of Abdelfattah et al. (2020) with some modifications (Table 1). Prior to welfare assessments, the three observers discussed the scoring protocol and practiced directly on sample ducks in the shed to ensure agreement on what was being observed, but no formal reliability testing was carried out. During scoring, any bird that an observer was unsure of was discussed among observers until a consensus was reached. Following scoring, the duck was placed back onto the ground to rejoin the flock. Each small group of ducks was corralled from an area on the opposite side of the shed to minimize scoring the same birds, but this possibility was likely not eliminated. Due to the fixed position of the weighing setup, it was not possible to gather birds from sample areas across the whole shed.

Once the catch-and-inspect scoring had finished, two observers completed a set of transect walks throughout each shed following the protocol of Abdelfattah et al. (2020). Prior to commencing the transect walks, observers practiced inside the shed and discussed the observations to ensure agreement. A total of four transects were carried out using the scoring system as detailed in Table 1. Any duck observed with damage was recorded as well as the specific welfare issues present. Individual ducks that presented with more than one form of damage were recorded across multiple categories. Transects ran down the length of the shed and were spread approximately equally across the shed width, while accommodating the positions of the drinker and feeder lines. Observers walked slowly down transect 1 in pairs, independently observing the left or right side each, then back up transect 3, down transect 2, and up transect 4 (inconsistently, in Cohort 2, the transect walks followed a sequential order due to experimenter error). All weighing/scoring and transect walks were completed in one shed by 11:00 and the second shed after 14:00 on the same day. The same welfare scoring protocols were carried out across sheds C and D when ducks reached 26 d of age. Sheds were assessed in pairs based on their initial staggered placement dates where two sheds were placed 2 d earlier than the remaining two sheds: See *Commercial sheds and setup* section. On day 33, a sample of approximately 150 birds from each shed was weighed/scored again and transect walks were completed once more before the ducks were removed from the shed for processing.

Misting application and video recording

From 11:00 until 14:00, the birds were left undisturbed by personnel for video recording across 3 h (11:00 to 14:00). The overhead misting system (1,000 psi, 0.2 size nozzles at a 45° angle, spaced 1.2 m apart down the length of the shed with output of 0.056 L/min, total 240 nozzles per shed) was manually turned on and run continuously from 12:00 until 13:00 in the misting treatment shed with the curtains closed during this hour to facilitate the water accumulating and reaching the birds (see Figure S1 for images of a duck shed prior to and during misting). This time of day was selected as a time in approximately the middle of the day, but that also fit within the farm schedule. The age of 26 d was selected as the earliest in which to wet the ducks in relation to their growth, feather coverage, and thermoregulatory capabilities. Given the limited period in which to apply the misting before load-out, there was no acclimation period prior to video-based behavioral data being collected from the first misting experience at 26 d onwards. Researchers present on site confirmed the mist was accumulating on surfaces at duck level (i.e., water visible on feeder and drinker lines) during the hour of operation across the whole shed. The curtains were also closed during the same hour in the nonmisted

Table 1. The welfare indicators that were scored during the catch-and-inspect (CAI) and transect walks (TW)[1]

Indicator	Score	Description
Feather quality (neck, wings, back, rump, chest)	1	Damaged feathers (worn/deformed/missing) with areas <5 cm in diameter at its largest
	2	Damaged feathers (worn/deformed/missing) with areas ≥5 cm in diameter at the largest point
Feather cleanliness (neck, wings, back, rump, chest)	1	Staining/discoloration on feathers <5 cm in diameter at its largest; includes staining from blood
	2	Staining/discoloration on feathers ≥5 cm in diameter at its largest; includes staining from blood
Blood on feathers	Y/N	Visible fresh or old blood
Eyes	1	Staining or dirt around the eye, or wet eye ring
	2	Inflamed eyelids, infected eyes (includes sealed shut), or blindness
Nostrils	1	One or both air passageways contain dust/mucus inside the nostril cavity
	2	One or both air passageways blocked from the outside (can include inside) where the nostril opening is plugged
Gait (TW)	1	Duck shows slight limp or walks awkwardly (e.g., crossed feet, stiffing of legs)
	2	Duck does not want to walk, will only walk short distances, typically shows obvious leg injury/swelling
Footpad (CAI)	1	Bloodless calluses or dermatitis lesions cover <50% of the pad area
	2	Calluses or dermatitis lesions cover ≥50% of the pads and/or bloody lesions present
Hocks	Y/N	Presence of damage/lesions/blood on the hocks
Inversion rubbing	Y/N	Presence of worn/lesioned patches on the wings from rubbing following inversion

[1] During the TW feather quality and cleanliness were combined into a single category per duck region. Primary feathers were still growing during the inspection periods; thus, ducks did not have full adult feather coverage. Dried blood sometimes clumped some of the feathers together. Y/N = Yes/No. Adapted from Abdelfattah et al. (2020).

sheds. The misting system made a noise as it was running, audibly similar to the noise of the feeder line according to the researchers. However, the noise was more prominent at the front of the shed where the pump was located, whereas the feeder line made noise across the length of the shed. The curtains were opened again following misting (13:00 to 14:00). Curtains could not be closed for longer as this reduced the open-air ventilation in the shed. The video recording period encompassed 1 h of video "prior" to misting, 1 h of video "during" misting, and 1 h of video "after" misting. Daily misting occurred at the same time until 33 d of age, except for the first day in sheds A and B where logistical constraints resulted in the observation period being from 12:00 until 15:00 (i.e., curtains were closed at 13:00 and misting occurred from 13:00 to 14:00). In Cohort 2, there were some higher ambient temperatures on days 28 and 29 (equated to days 27 and 28 for shed C) which resulted in temperatures above 26 °C within the shed and required the misting system to be turned on for a short period of time (approximately 5 min) during the observation hours to reduce shed temperature in the nonmisting shed (these data were removed from the behavioral analyses). Daily mortality and culls across the trial period were recorded by the farm staff.

Video observations

The video recordings were decoded by two observers who initially trained together on the same section of video to ensure minimum 85% interobserver reliability as assessed by correlation analysis in Microsoft Excel. Some infrequent behaviors were less reliable between observers and thus were later categorized together as "other" behaviors and not statistically analyzed (see *Data and statistical analyses* section). Video recordings from 4 cameras within each shed (total 16 cameras) across 8 d (day 26 to day 33) were decoded across the 3-h observation period. Point observations were made every 10 min by watching a 5-s video clip to confirm the behavior of each duck within the selected frame. The total number of ducks with their bodies visible (i.e., a duck with only a portion of its body within the frame was not included) was first counted to then calculate the proportions of ducks performing each behavior. The behaviors observed are listed in Table 2. In total, n = 2,393 data points were recorded per behavior for Cohort 1 (19 observation points × 8 d × 4 cameras × 4 sheds − 39 missing data points due to video system failure) and n = 1,805 per behavior for Cohort 2 (19 observation points × 8 d × 4 cameras × 3 sheds − 19 observation points where one camera failed to record on day 32 in shed A).

Preliminary observations in Cohort 1 indicated the misted ducks were drinking more during misting and preening more after misting than the nonmisted ducks. Thus, some exploratory focal observations were carried out by one researcher (using The Observer XT 12.0, Noldus Information Technology, Wageningen, The Netherlands) on one misted and one nonmisted shed using one camera on day 32 in the hour after misting. Four random time points were selected where there were sufficient ducks visible that were drinking to enable

Table 2. Ethogram of the behaviors recorded during video observations of the ducks

Behavior	Description
Allopreening	Duck uses its bill to preen another duck without it moving away
Body shaking	Duck shakes its entire body
Conspecific dabbling	Duck dabbles at another duck with its bill causing it to move away
Drinking	Duck has bill up to the water nipples and is drinking water
Environmental pecking	Duck pecks at inanimate objects with its bill
Panting	Duck stands or lies down with an open mouth
Preening	Duck uses bill to groom its own feathers
Rooting litter	Duck dabbles its bill in the floor litter
Scratching	Duck scratches itself with one foot
Sitting	Duck is sitting down on the litter to rest (eyes open), or sleep (eyes closed)
Standing	Duck is upright with both feet on the ground but stationary
Stretching	Duck stretches out a foot or wings then retracts them
Tail wagging	Duck wags its tail rapidly
Walking	Duck is locomoting with its feet from one location to another
Wing flapping	Duck flaps both wings simultaneously

following of six individuals for 2 min, documenting all exhibited behaviors across that 2-min period. The baseline behaviors documented were sitting, standing, running (only one duck was observed doing this), walking, or out of view (when the duck moved out of the camera view). Active behaviors categorized in addition to the base behaviors were allopreening, body shaking, drinking, preening, rooting litter, stretching, tail wagging, and wing flapping (see Table 2 for further descriptions of each behavior). These observations were conducted to determine if there was a clear pattern of using the drinkers to enable wet preening.

Data and statistical analyses

All analyses on both cohorts combined were conducted in JMP® 16.1.0 (SAS Institute, Cary, NC, United States) with α set at 0.05 and a trend considered as > 0.05 < 0.10. Restricted maximum likelihood (REML) estimation methods were applied to the general linear mixed models (GLMMs). Where significant differences were present, post-hoc Student's *t*-tests were conducted on the least squares means with Bonferroni correction applied when there were more than four post-hoc comparisons.

The temperature data were compiled for the 3-h observation period of each day both inside and outside the shed. Readings across the multiple sensors in each location (2 × sensors outside, 3 × sensors per shed inside) were averaged to provide one mean value per 15 min representing inside and outside temperatures (total dataset inside $n = 672$: 12 readings × 8 d × 7 sheds). The temperature readings outside were matched according to the start dates for the trial period for each shed based on the staggered placement of ducklings (i.e., sheds A and B in Cohort 1 started 2 d earlier than sheds C and D, sheds A and B in Cohort 2 started 1 d earlier than shed C). All temperature data were visually displayed, and a GLMM was applied to the indoor temperature data only with the fixed effects of treatment (misted, nonmisted), treatment time (prior, during, after), and their interaction and random effects of "time," "age," "shed," and "cohort." The humidity data in the misted sheds showed saturation (100% humidity) during the misting period which then resulted in multiple subsequent false readings with some of the sensors (i.e., from 100% to 0% humidity 15 min afterward) and thus the humidity data were unreliable and could not be analyzed further.

The scores from the catch-and-inspect sampling were compiled per individual duck across age (26 or 33 d) per shed for misted and nonmisted treatments. The final dataset comprised $n = 1{,}253$ ducks for the misted treatment and $n = 959$ ducks for the nonmisted treatment across both cohorts. Individual body weight data were analyzed using a GLMM comparing the fixed effects of age and treatment and included the random effects of "shed" and "cohort." Only three ducks were observed with eye issues (score 1) and no ducks were observed with hock issues, so these data were not analyzed further. Similarly, only four ducks were recorded with feather quality or cleanliness issues on the neck (scores 1 and 2), only three ducks with poor feather quality on the chest (scores 1 and 2), only two ducks with poor feather quality on the rump (scores 1 and 2) at 26 d of age (more ducks observed at 33 d of age), and only six ducks with feather cleanliness issues on the rump (score 1) at 26 d of age; thus, these data were not analyzed. All other welfare indicators were analyzed using multiple Pearson's chi-square tests to examine the effect of treatment at 26 and 33 d of age separately, blocking for the effect of "shed."

The total number of birds recorded with some form of damage during the transect walks was summarized per shed. Ducks displaying specific welfare indicators were calculated as the proportion of the total number of observed ducks with damage and not the proportions of total ducks in the shed. Proportions were calculated per transect walk per shed both at the start (26 d) and at the end (33 d) of the misting period across both cohorts (total dataset $n = 56$ per welfare indicator: four transect walks × seven sheds × two age points). These data were analyzed using multiple Wilcoxon signed-rank tests to assess the effect of the misting treatment at the start (no misting had commenced so no treatment differences were expected) and at the end of the 8-d misting period.

The mortality and cull data were summed to provide a single value per day per shed across the trial period (total dataset

$n = 56$: 8 d × 7 sheds). These data were not normally distributed and were analyzed via a Wilcoxon signed-rank test to compare the effect of misting treatment.

The behavioral observation data were converted into proportions of the total ducks observed within the video frame performing each behavior. The proportions were then compiled per each of the 15 behaviors for each time point in each shed across both cohorts, totaling a final dataset of $n = 4198$ per behavior. The behaviors of "allopreening," "body shaking," "conspecific dabbling," "wing flapping," "environmental pecking," and "scratching" were observed infrequently and were combined into a single category of "other" behaviors, presented graphically but with no statistical analyses conducted. The 2 d of higher temperatures in Cohort 2 were removed from the final dataset and then each observation time point was averaged across the 8 d of the trial period. Thus, the final behavioral dataset consisted of $n = 532$ (19 observation points × 4 cameras × 7 sheds) per each behavior of "drinking," "panting," "preening," "rooting litter," "sitting," "standing," "stretching," "tail wagging," and "walking." Behavioral data were logit-transformed and analyzed separately using GLMMs with the fixed effects of treatment, treatment time and their interaction, and random effects of "time," "shed," "camera," and "cohort.". The studentized residuals were inspected for visual homoskedasticity. The exploratory focal observations of individual ducks are visually displayed in Figure S2).

Results

Environmental temperatures

Figure 1 shows the ambient outside and inside shed temperatures across the 8-d trial period for the misted and nonmisted sheds in Cohort 1 and Cohort 2. The ambient temperatures were cooler in Cohort 1 than Cohort 2 based on differing seasons (autumn vs. spring, respectively). Generally, temperatures were cooler inside the sheds than ambient temperatures outside (Figure 1). There was a significant interaction between treatment and treatment time for the indoor temperatures ($F_{2,\,710.9} = 20.48$, $P < 0.0001$) where the nonmisted shed had higher temperatures than the misted sheds during and after but not prior to the misting application (Figure 1). The water kept the misted sheds cooler when the curtains were closed.

Welfare indicators

There was a significant interaction between treatment and age for body weight ($F_{1,\,2206} = 26.60$, $P < 0.0001$) but post-hoc tests only differentiated by age, with ducks in both treatment groups increasing in body weight as expected (LSM ± SEM misted at 26 d: 2.17 ± 0.10 kg; nonmisted at 26 d: 2.24 ± 0.10 kg; misted at 33 d: 3.0 ± 0.10 kg; nonmisted at 33 d: 2.97 ± 0.10 kg). Table 3 displays the Pearson's chi-squared test results for the effect of misting treatment on welfare indicators assessed during catch-and-inspect. At 26 d, just prior to the start of the treatment period, the nonmisted ducks had dirtier chest feathers ($P < 0.0001$), less footpad dermatitis ($P = 0.0005$) and showed trends for better feather quality on the back ($P = 0.08$), and wings ($P = 0.08$) and a lower presence of blood ($P = 0.08$, Table 3). At 33 d of age, there were no longer significant treatment effects on feather quality of the chest ($P = 0.97$, Table 3) or differences in footpad dermatitis ($P = 0.30$). However, there were significant differences between treatment groups in feather quality on the back with the nonmisted ducks showing more birds with poorer quality ($P = 0.0001$, Table 3). In contrast, the misted ducks showed poorer feather cleanliness on the back ($P < 0.0001$, Table 3). The nonmisted ducks showed poorer feather quality on the wings ($P = 0.01$, Table 3), but the misted ducks showed poorer feather cleanliness on the wings ($P < 0.0001$, Table 3). The misted ducks showed a higher presence of blood than nonmisted ducks at 33 d of age ($P < 0.001$, Table 3). Proportions of blood across each assessed flock indicated variation depending on the cohort and the flock (Cohort 1: 14% to 35%; Cohort 2: 68% to 91%), and this was observed to be from broken/damaged pin feathers predominantly on the wings rather than any broken skin. Across all ducks, the most prevalent welfare indicators observed were nostril cleanliness, footpad dermatitis, cleanliness of the chest, back, and wing feathers, and presence of blood.

There were no significant differences in any of the welfare variables assessed during the transect walks between misted and nonmisted sheds at the start of the misting period before any treatment had begun ($\chi^2 = 0.003$ to 2.78, df = 1, $P \geq 0.10$, Table 4). There were also no significant differences in any of the welfare variables between misted and nonmisted sheds at the end of the misting period after the treatment had been applied ($\chi^2 = 0.005$ to 1.40, df = 1, $P \geq 0.24$, Table 4).

There was no significant difference in the total mortality across the trial period between the misted and nonmisted sheds ($\chi2 = 0.91$, df = 1, $P = 0.34$), and the overall mortality was low across all sheds (misted: $n = 306$ ducks across four sheds, nonmisted: $n = 264$ ducks across three sheds).

Behavior

Figure 2 displays the proportions of ducks exhibiting each behavior across both cohorts for the misted and nonmisted treatment groups, prior to, during, and after the misting period. The most prevalent behavior observed was ducks sitting down on the litter resting/sleeping, which occupied most of the observations, followed by drinking, panting, and preening in similar proportions.

Analyses showed there was a significant interaction between treatment and treatment time for the proportion of ducks drinking ($F_{2,\,514.5} = 28.36$, $P < 0.0001$) with misted ducks showing a greater increase in drinking during the misting period relative to the increase in the nonmisted ducks (Table 5). The misted ducks showed more drinking during and after misting relative to their drinking prior, whereas the nonmisted ducks showed their most drinking after the misting period (Table 5). There was also a significant effect of treatment time ($F_{2,\,410} = 9.10$, $P = 0.0001$) with more drinking after the misting period than prior or during. There was no overall effect of treatment ($F_{1,\,1.84} = 0.52$, $P = 0.55$).

There was a significant interaction between treatment and treatment time for the proportion of ducks panting ($F_{2,\,515.7} = 5.89$, $P = 0.003$) with the nonmisted ducks showing an increase in panting during the misting period (when the curtains were closed) relative to what they showed prior (Table 5). There was a significant effect of treatment time ($F_{2,\,224.1} = 3.12$, $P = 0.046$) with less panting prior to than during misting and borderline more panting in the nonmisted ducks ($F_{1,0.73} = 914.35$, $P = 0.05$).

There was a significant interaction between treatment and treatment time for the proportion of ducks preening ($F_{2,\,515.9} = 13.54$, $P < 0.0001$) with the misted ducks showing their least preening during the misting period and their most preening

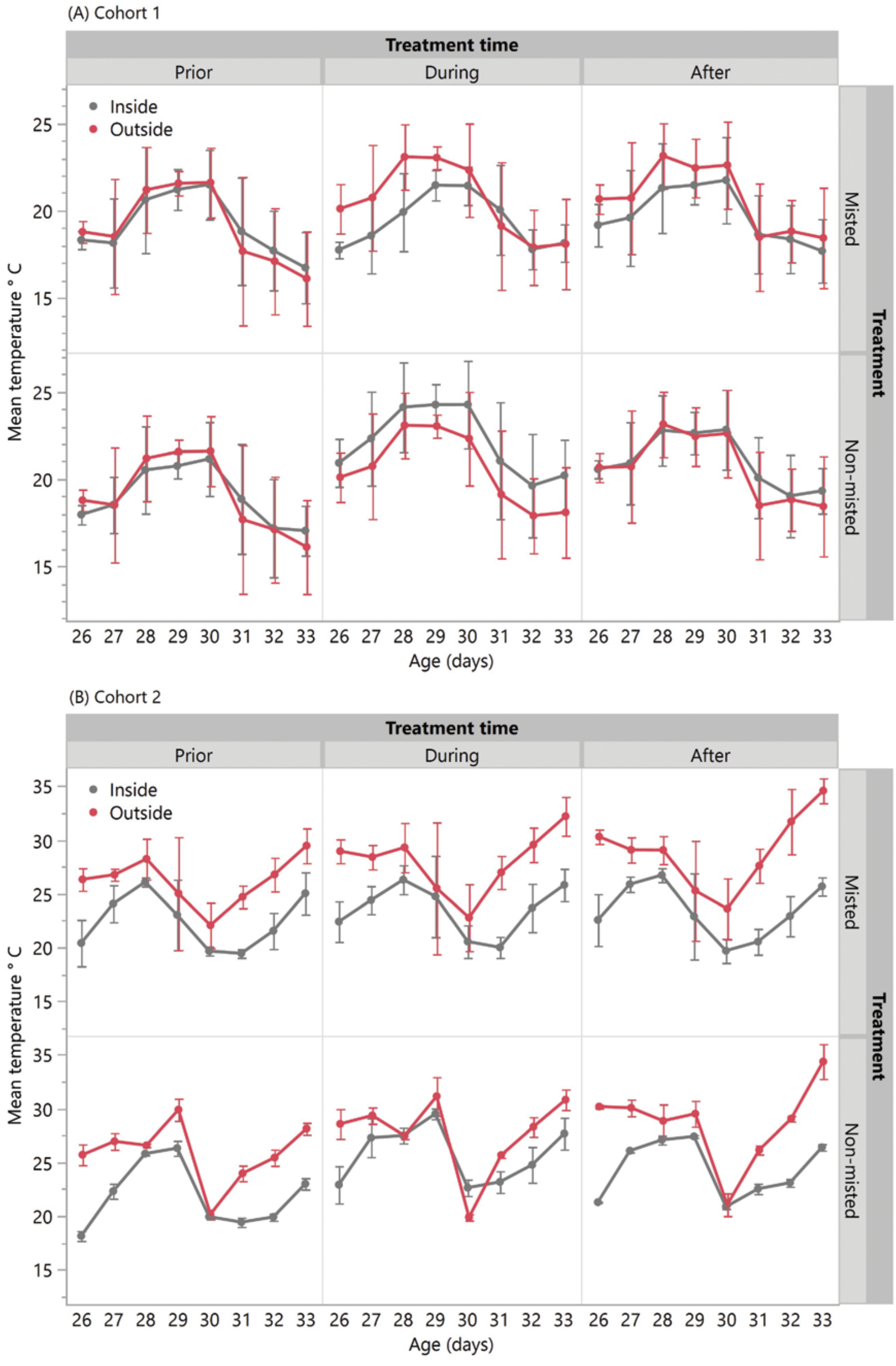

Figure 1. The mean (±SD) ambient outside and inside shed temperature across duck age prior to, during, and after a misting treatment for both misted and nonmisted (control) sheds for Cohort 1 (A) and Cohort 2 (B). Note the different scales in the y-axis between the two cohorts.

after the misting period (Table 5). The nonmisted ducks showed similar preening prior to and during the misting period, and the most preening after the misting period. The misted ducks showed less preening than the nonmisted ducks during misting. There was also a significant effect of treatment time ($F_{2,\ 103.5} = 41.21$, $P < 0.0001$) with more preening after the misting period and the least preening during misting. There was a borderline significant overall effect of treatment ($F_{1,\ 1.18} = 82.59$, $P = 0.05$).

There was a significant interaction between treatment and treatment time for the proportion of ducks rooting in the litter ($F_{2,\ 514.8} = 20.90$, $P < 0.0001$). The misted ducks showed their most rooting in the litter prior to the misting period whereas the nonmisted ducks showed similar proportions across all treatment time periods (Table 5). There was also a significant effect of treatment time ($F_{2,\ 319} = 5.84$, $P = 0.003$) with more rooting in the litter shown prior to misting than during. There was no overall effect of treatment ($F_{1,\ 2.07} = 3.15$, $P = 0.21$).

Table 3. The percentage of the scored ducks during catch-and-inspect within both treatment groups (misted, nonmisted) that showed the presence of a specific welfare indicator at 26 and 33 d of age, representing the start and end of the misting treatment period, respectively[1]

		Nostrils	FC Chest	FQ Back	FC Back	FQ Wing	FC Wing	FQ Rump	Footpad	Inversion rubbing	Blood (Y)
Treatment	Age (d)	Score 1	Score 1	Score 1	Score 1	Score 1	Score 1		Score 1		
Misted	26	40.0	34.5	2.0	22.8	3.2	19.5		75.04	2.0	45.5
Nonmisted	26	39	29.5	1.0	20.5	1.6	18.5		65.75	1.6	40.3
		Score 2	Score 2	Score 2	Score 2		Score 2				
Misted	26	1.5	55.0	0.6	5.8		0.5				
Nonmisted	26	2.5	67.1	0	5.9		0.4				
Test statistics		$\chi^2 = 1.63$ df = 2 n = 1,161 $P = 0.44$	$\chi^2 = 31.12$ df = 2 n = 1,161 **$P < 0.0001$**	$\chi^2 = 5.06$ df = 2 n = 1,161 $P = 0.08$	$\chi^2 = 0.93$ df = 2 n = 1,161 $P = 0.63$	$\chi^2 = 3.3$ df = 2 n = 1,051 $P = 0.08$	$\chi^2 = 0.2$ df = 2 n = 1,161 $P = 0.91$		$\chi^2 = 11.97$ df = 2 n = 1,161 **$P = 0.0005$**	$\chi^2 = 2.6$ df = 2 n = 1,161 $P = 0.27$	$\chi^2 = 3.06$ df = 2 n = 1,161 $P = 0.08$
		Score 1	Score 1	Score 1	Score 1	Score 1	Score 1	Score 1	Score 1		
Misted	33	43.2	23.5	0.7	33.2	3.0	46.5	4.8	68.0	2.2	53.8
Nonmisted	33	45.2	22.8	3.6	14.6	4.9	31.9	3.1	69.0	2.7	40.8
		Score 2	Score 2	Score 2	Score 2	Score 2	Score 2	Score 2	Score 2		
Misted	33	5.0	68.0	1.0	5.7	1.2	6.5	1.8	0.50		
Nonmisted	33	4.7	68.7	3.1	3.6	3.3	3.3	2.7	1.33		
Test statistics		$\chi^2 = 0.46$ df = 2 n = 1,051 $P = 0.80$	$\chi^2 = 0.07$ df = 2 n = 1,051 $P = 0.97$	$\chi^2 = 18.2$ df = 2 n = 1,051 **$P = 0.0001$**	$\chi^2 = 55.3$ df = 2 n = 1,051 **$P < 0.0001$**	$\chi^2 = 8.57$ df = 2 n = 1,051 **$P = 0.01$**	$\chi^2 = 33.9$ df = 2 n = 1,051 **$P < 0.0001$**	$\chi^2 = 2.71$ df = 2 n = 1,051 $P = 0.26$	$\chi^2 = 2.38$ df = 2 n = 1,051 $P = 0.30$	$\chi^2 = 0.27$ df = 2 n = 1,051 $P = 0.60$	$\chi^2 = 17.5$ df = 2 n = 1,051 **$P < 0.001$**

[1] The results of the Pearson's chi-squared test between treatment groups are presented with significant *P*-values indicated in **bold**. FQ, feather quality; FC, feather cleanliness; Y, Yes. See Table 1 for a full description of the welfare indicators and scores.

Table 4. The mean (±SEM) percentages of total observed ducks with damage showing each specific welfare indicator as assessed by transect walks[1]

Treatment	Time period	Welfare measure									
		Feather Q/C neck	Feather Q/C back	Feather Q/C rump	Feather Q/C wings	Inversion damage	Blood	Hocks	Gait mild	Gait worse	Total observed ducks
Misted	Start	0.5±0.1	6.0±1.0	0.4±0.1	3.0±1.0	4.0±1.0	89±2.0	0.3±0.2	1.0±0.4	1.0±0.4	246±51.5
Nonmisted	Start	0.4±0.2	6.0±1.0	0.9±0.3	4.0±1.0	3.0±1.0	88±2.0	0.5±0.2	1.0±0.4	1.0±5.0	231.4±54.6
Misted	End	1.0±0.3	9.0±2.0	15.0±4.0	10.0±2.0	2.0±0.4	74±5.0	0.3±0.1	2.0±0.6	4.0±2.0	285.6±48.6
Nonmisted	End	1.0±0.5	9.0±2.0	22.0±5.0	14.0±3.0	2.0±0.6	67±7.0	0.06±0.07	1.0±0.4	2.0±0.6	229.3±52.24

[1] Values are presented for misted and nonmisted treatment sheds at the start of the misting treatment period (26 d of age) and at the end of the misting treatment period (33 d of age).

There was a significant interaction between treatment and treatment time for the proportion of ducks sitting ($F_{2,\,514.5}$ = 7.03, P = 0.001) with both the misted and nonmisted ducks showing the most sitting prior to the misting treatment and the least after the misting treatment (Table 5). There was also a significant effect of treatment time ($F_{2,\,504.2}$ = 46.13, P < 0.0001) with the most sitting prior to the misting treatment and the least afterwards. There was no overall effect of treatment ($F_{1,\,1.61}$ = 0.37, P = 0.62).

There was a significant interaction between treatment and treatment time for the proportion of ducks standing ($F_{2,\,515.6}$ = 19.05, P < 0.0001) with the nonmisted ducks showing less standing during the misting period relative to afterwards whereas the misted ducks showed consistent proportions (Table 5). There was a significant effect of treatment time ($F_{2,\,327.5}$ = 4.11, P = 0.02) with the most standing after the misting period but no significant effect of treatment ($F_{1,\,1.6}$ = 0.02, P = 0.89).

There was a significant interaction between treatment and treatment time for the proportion of ducks stretching ($F_{2,\,514.3}$ = 11.23, P < 0.0001) with the misted ducks showing less stretching during the misting period relative to prior but the nonmisted ducks showed similar proportions across all time periods (Table 5). There was no overall significant effect of treatment time ($F_{2,\,1.67}$ = 3.12, P = 0.27) nor an overall significant effect of treatment ($F_{1,\,2.07}$ = 2.43, P = 0.26).

There was a significant interaction between treatment and treatment time for the proportion of ducks showing tail wagging ($F_{2,514.3}$ = 7.63, P < 0.0005) with the misted ducks showing more tail wagging during misting than prior to (Table 5). There was no overall significant effect of treatment time ($F_{2,2.28}$ = 0.59, P = 0.62) or treatment ($F_{1,2.04}$ = 0.23, P = 0.68).

There was a significant interaction between treatment and treatment time for the proportion of ducks walking ($F_{2,\,515.3}$ = 11.87, P < 0.0001) with the misted ducks showing more walking during misting than prior to it (Table 5). There was no significant effect of treatment time ($F_{2,\,114.9}$ = 0.93, P = 0.40) or treatment ($F_{1,\,2.01}$ = 0.20, P = 0.70).

The focal observations of individual ducks in one misted and one nonmisted shed during the after-misting hour on day 32 indicated some ducks were drinking followed by preening, alternating between the two across the 2-min period (Figure S2). This suggests some ducks may have been wet preening from the drinker lines, with individuals in both misted and nonmisted sheds observed doing this (Figure S2).

Discussion

This study was carried out to determine if the application of overhead misting to commercial grower ducks for 1 h daily would be an effective method of water delivery to wet the ducks and facilitate behavior and welfare improvements without significant welfare compromises. The results showed the misting application predominantly had impacts on the patterns of behavioral change across the treatment time periods between the misted and nonmisted ducks rather than increasing or decreasing the overall expression of specific behaviors. There were also some differences between the treatment groups in feather cleanliness, but these were likely a result of pre-existing differences between individual flocks in blood staining from pin feathers. The majority of welfare indicators showed no positive or negative effect of the misting treatment

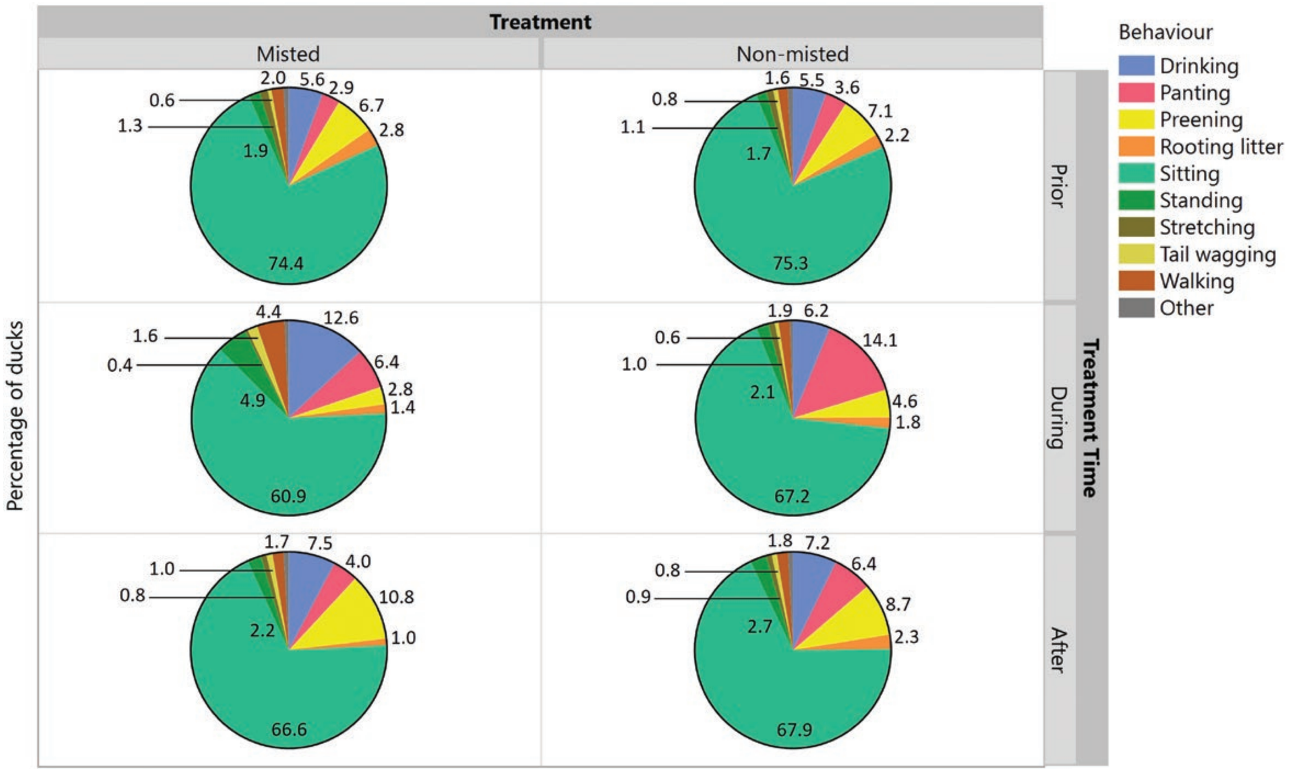

Figure 2. The percentage of observed ducks exhibiting each behavior across misted and nonmisted treatment groups, prior to, during, and after the misting treatment including indicated percentage values. "Other" included behaviors of allopreening, body shaking, conspecific dabbling, environmental pecking, scratching, and wing flapping. This category is located between "walking" and "drinking" but the small values of ≤0.15% prohibit clear display of values. Raw data are presented.

with few ducks overall exhibiting severe welfare indicators.

Further research with larger water droplet sizes resulting in

Table 5. The least squares means (±SEM) proportions of ducks performing each behavior prior to, during, and after a misting treatment for both misted and nonmisted (control) groups

Treatment	Behavior	Prior	During	After
Misted	Drinking	0.08 ± 0.01^{d}	0.14 ± 0.01^{abc}	0.16 ± 0.02^{ab}
Nonmisted		0.08 ± 0.01^{bcd}	0.07 ± 0.01^{cd}	0.16 ± 0.02^{a}
Misted	Panting	0.04 ± 0.02^{bc}	0.06 ± 0.02^{bc}	0.06 ± 0.02^{c}
Nonmisted		0.05 ± 0.02^{bc}	0.14 ± 0.02^{a}	0.08 ± 0.02^{ab}
Misted	Preening	0.05 ± 0.008^{b}	0.03 ± 0.005^{c}	0.19 ± 0.01^{a}
Nonmisted		0.06 ± 0.008^{b}	0.05 ± 0.006^{b}	0.17 ± 0.01^{a}
Misted	Rooting litter	0.04 ± 0.006^{a}	0.02 ± 0.004^{b}	0.02 ± 0.006^{b}
Nonmisted		0.03 ± 0.006^{ab}	0.02 ± 0.004^{ab}	0.03 ± 0.006^{ab}
Misted	Sitting	0.72 ± 0.04^{a}	0.63 ± 0.04^{b}	0.47 ± 0.04^{c}
Nonmisted		0.71 ± 0.04^{a}	0.65 ± 0.04^{b}	0.45 ± 0.04^{c}
Misted	Standing	0.03 ± 0.005^{ab}	0.05 ± 0.002^{ab}	0.04 ± 0.006^{ab}
Nonmisted		0.03 ± 0.005^{ab}	0.02 ± 0.002^{b}	0.04 ± 0.006^{a}
Misted	Stretching	0.007 ± 0.002^{a}	0.004 ± 0.001^{b}	0.005 ± 0.003^{ab}
Nonmisted		0.006 ± 0.002^{ab}	0.01 ± 0.001^{ab}	0.005 ± 0.003^{ab}
Misted	Tail wagging	0.006 ± 0.004^{b}	0.02 ± 0.004^{a}	0.01 ± 0.004^{ab}
Nonmisted		0.007 ± 0.004^{ab}	0.005 ± 0.004^{ab}	0.01 ± 0.004^{ab}
Misted	Walking	0.02 ± 0.008^{b}	0.05 ± 0.006^{a}	0.03 ± 0.009^{ab}
Nonmisted		0.02 ± 0.008^{ab}	0.02 ± 0.006^{ab}	0.03 ± 0.009^{ab}

[a–d] Dissimilar superscript letters indicate differences in the means across both the treatment time and treatment groups per behavior. All interaction terms were $P \le 0.003$. Analyses were conducted on logit-transformed proportions with a constant of 0.00001 added to accommodate values of "0" for all behaviors.

greater accumulation of surface water or longer durations of misting may show greater impacts on the ducks.

The welfare indicators assessed on samples of individual ducks as well as across the whole shed found few differences in welfare indicators between the misted and nonmisted treatment sheds. There were differences in some factors at the initial assessment age before treatments had been implemented, indicating pre-existing differences between the sheds. While the ducks in the misted sheds presented poorer feather cleanliness on the wings and back, this was predominantly due to more blood in the initial scores before the treatment period commenced indicating inherent shed/flock differences in this welfare indicator. In general, more ducks were observed with feather cleanliness rather than feather quality issues, again primarily related to the blood from damaged wing pin/blood feathers or staining on the chest from resting on the litter. The presence of blood (fresh or dried) was the most common welfare indicator observed in the transect walks in the current study, but only approximately half the ducks scored during catch-and-inspect showed blood on the feathers. The presence of blood has previously been reported to be one of the most common welfare indicators in commercial Pekin duck flocks as assessed in the United States via similar inspection methods (Abdelfattah et al., 2020). Blood from duck pin feathers may result from picking behavior, and/or may be exacerbated by picking (Colton and Fraley, 2014), but to date, there has not been extensive research into the issue and the relationship between these factors (Makagon and Riber, 2022). Based on the definitions of self- and conspecific picking provided in Dong et al. (2021), these behaviors were not observed within the current study. However, it is possible picking behaviors were missed within the video observation period chosen or occurred at earlier ages. This limitation should be addressed in future studies where observations across the whole grower period would provide valuable insight into behavioral patterns across age. Given the large differences in blood between cohorts in the current study, further research should be directed toward understanding the causes of this in duck strains housed in Australian conditions, strategies to mitigate its inconsistent occurrence, and any welfare effect it may be having on the ducks. The observation of only seven grower flocks on one commercial farm limits the generalization of the current study results.

Other prevalent welfare indicators in the current study were footpad dermatitis and nostril cleanliness, for which comparatively high proportions (relative to other indicators) of affected ducks were also observed in commercial flocks in the United States (Abdelfattah et al., 2020). This suggests these are typical welfare indicators that are present in commercial grower Pekin ducks and are likely a result of the strain selection, growth rates, and housing environments. However, the indicators of footpad dermatitis and nostril cleanliness in the current study were not severe, with few ducks presenting with the worst scores. The nostrils were categorized even with partial blockage which may be expected given the frequent litter management that occurs in the sheds to maintain quality of the wood shavings. Previous research internationally has showed worse nostril scores for those ducks housed on litter versus plastic slats but not across all age points assessed (Fraley et al., 2013). Distinct from observations reported on commercial farms internationally (Abdelfattah et al., 2020), the ducks in the current study presented almost no eye health indicators suggesting this may not be as high a concern for commercial birds on Australian farms. Overall, the majority of ducks were in good condition which aligns with reports on grower duck welfare internationally (Jones and Dawkins, 2010a; Fraley et al., 2013; Karcher et al., 2013).

The misting application had an impact on observed behaviors, but this was largely through changes in the behavioral patterns exhibited across the periods prior to, during, and after the misting application rather than affecting the overall proportions of the observed behaviors. The changes in behavior across time in the nonmisted ducks were potentially affected by the closure of the curtains during the corresponding treatment misting period. It is possible that high humidity from the misters in combination with the ambient indoor temperature influenced misted ducks' core body temperature, leading to changes in drinking behavior during and after misting; however, no increase in panting was observed in misted ducks. Conversely, the indoor temperature in nonmisted barns was higher than in misted barns during the misting period, and similar to misted ducks, a higher percentage of nonmisted ducks increased their drinking behavior after the curtains had been closed (but not during). The increase in the drinking behavior of nonmisted ducks was accompanied by an increase in the percentage of ducks that were panting during the misting treatment period, indicating that these ducks may have increased their drinking behavior to lower their body temperature. Future work should aim to conduct more detailed on-bird assessments in relation to thermal load such as respiration rate and body temperature. The saturation of the humidity sensors in the current study prevented accurate heat load index calculations, which is a limitation to also be addressed. Observing misting application in fully enclosed sheds would eliminate curtain closure impacts.

Other possible explanations for the increase in drinking behavior observed in misted ducks may be that these ducks were already actively interacting with water, or that the sound of the mister turning on stimulated drinking behavior. This was not predicted, and it is uncertain if the water application itself stimulated the birds to seek out a water source, possibly for further wet preening, or if the sound of the misting system operating triggered a similar response in the ducks to what is seen when the feeder lines start running (anecdotal observations on farm). Further studies controlling for the noise of the misting line would be needed to confirm this as this was not a factor that was considered in the design of the current study. It was predicted that the misted ducks would show more preening during the misting application but instead, they showed less during misting and more afterwards. The nonmisted ducks also showed more preening afterwards; however, the misted ducks showed a greater increase from during misting to after misting. The misted ducks may have shown less preening during the hour of misting as they were occupied with other behaviors such as drinking, and then exhibited more preening afterwards when their feathers would have been wet. The increase in both treatment groups suggests there were also curtain closure and/or time of day effects on this behavior. The increase in walking during the misting hour for the misted ducks corresponds with the misting treatment stimulating the ducks to increase activity, and more tail wagging corresponds with typical duck behavior when wetted. The increase in activity may have other positive benefits on duck health, such as improving duck gait; previous research showed poorer gait resulted in more panting, less time at the drinkers, and more time resting (Jones and Dawkins, 2010b). While poor gait was not observed to be a significant welfare issue in the current flocks, stimulation for increased activity may have benefits for flocks where this is a (predicted) welfare concern.

Differences in behavior prior to, during, and after misting may also have captured typical variation across the hours of the day in the ducks' behavioral expression. Previous observations of duck behavior internationally have indicated ducks are more active in the morning (08:00 to 11:00) and evening (18:00 to 21:00) and thus do show changes in behavioral expression across the day. Observations of ducks in Australian grower sheds across a 24-h period would confirm how time budgets change across the day. The restricted time period for observations in the current study limited the interpretation of time-of-day impacts on behaviors. Overall, all ducks spent a large proportion of their time resting on the litter, and this aligns with observations internationally (Jones and Dawkins, 2010b). This suggests that genetic selection for fast growth rates may be the primary driver of the behavioral patterns of grower ducks, where any changes as a result of misting application may be subtle. The value for the ducks of small increases in behaviors such as preening, or opportunities for wet preening would need to be further verified. Even without substantial changes in behavioral time budgets, the provision of water via overhead misting may increase positive experiences for the ducks, in line with recent drivers toward positive welfare and well-being for livestock animals (Mellor, 2015).

The misting application in the current study produced fine droplets of water typically used for reducing the shed temperature. The system was able to surface wet the ducks by closing the curtains and running for an extended period. A misting period of 1 h daily was selected as a starting point for a water treatment that may satisfy some water-related needs of the ducks and improve nostril and feather cleanliness without significant compromises to other health and welfare indicators. It is possible that a longer period of misting time or occurring at a different time of day may have resulted in different outcomes, but this remains to be investigated. Extended periods of water application may be more feasible for enclosed sheds that have automated ventilation and do not need curtains to be closed to allow the mist to settle, which reduces ventilation and increases shed temperatures. However, the potential effects of more water on litter quality and the change in litter management that may be required to mitigate negative impacts on environmental quality and bird health would need to be taken into account. Considerations will also need to be made for wetting birds during cooler months in open-sided sheds where the colder temperatures caused by the water application may cause significant cold stress in developing birds. Lower pressure misting systems that produce larger droplets of water resulting in greater surface wetting may have greater impacts on the ducks both in terms of their preening and cleanliness. Future research should aim to assess these systems to determine if the positive impacts will be greater without corresponding decreases in duck health. Industry system sustainability must still be considered when striving to reach a solution on a commercial level for providing water to ducks.

In conclusion, this study determined that the application of overhead misting to commercial grower ducks for 1 h daily was able to wet the ducks and resulted in some subtle behavioral changes. There were no negative welfare impacts but also no positive changes in external welfare indicators observed. Future work should build upon these results to further assess how overhead water may improve behavioral repertoires for commercial grower ducks.

Supplementary Data

Supplementary data are available at *Journal of Animal Science* online.

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Conflict of Interest statement

This research was supported in part by the Australian duck industry, but they did not play a role in study design, data collection, or data analysis. No other conflicts of interest are declared.

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