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Assessing behaviour and welfare impacts of water provision via misters in commercial ducks

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AgriFutures™ Chicken Meat

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In submitting this report, the researcher has agreed to Poultry Hub Australia publishing this material in an edited form.

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Project Summary

Project Title	Assessing behaviour and welfare impacts of water provision via misters in commercial ducks
Project No.	20-220
Date	Start: 01/10/2020 End: 01/03/2022
Project Leader(s)	Dr Dana Campbell
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Project Aim	The aim of the research was to measure the environmental, behavioural, and welfare impacts of water provision via a misting system for commercial grower ducks.
Background	Ducks are motivated to access water to maintain feather condition and exhibit natural water-related behaviours such as wet preening. Providing water to ducks on commercial farms is challenging as it can reduce litter and air quality and may increase bacterial contamination leading to increased duck mortality or illness. Providing water in a safe and effective manner to commercial ducks would improve their welfare, set the Australian duck industry as a world leader in duck welfare and husbandry, would meet proposed revised regulatory standards and maintain the duck industry's social licence to operate.
Research Outcome	The misting application predominantly had impacts on the patterns of behavioural change across the treatment time periods between the misted and non-misted ducks rather than increasing or decreasing overall expression of specific behaviours. There were also some differences between the treatment groups in feather cleanliness, but these may have been a result of pre-existing differences between sheds. The majority of welfare indicators showed no positive or negative effect of the misting treatment. Thus, overhead misting does affect duck behaviour without compromising their welfare, but further research with larger water droplet sizes resulting in greater accumulation of surface water may have greater impact on the ducks.
Impacts and Outcomes	This research provides evidence of the impacts of high pressure misting for surface wetting of grower ducks. Misting can affect patterns of behaviour in the ducks without compromising their welfare but does not increase overall behavioural expression. Misting for a longer period of time, or lower pressure misting with greater bird saturation, may have more significant effects. Further research should seek to understand if lower pressure misting with increased bird saturation would have more substantial impacts, and what the effects of different schedules of misting application such as multiple misting periods across the day, or increased duration of misting would be on duck behaviour and welfare. Objective baseline welfare data indicate areas where the industry is performing well, and areas where improvements could be made.
Publications	One in preparation

Executive Summary

Ducks are motivated to access water to maintain feather condition and exhibit natural water-related behaviours such as wet preening. Providing water to ducks on commercial farms is challenging as it can reduce litter and air quality and may increase bacterial contamination leading to increased duck mortality or illness. The aim of the research was to measure the environmental, behavioural, and welfare impacts of water provision via a misting system for commercial grower ducks.

Research was conducted on commercial duck grower farms in Victoria comparing treatment versus non-treatment (control) sheds. A total of 7 grower flocks were observed (4 misted, 3 non-misted) during May 2021 and November 2021. The sheds were open sided with exposure to ambient temperatures and natural ventilation. From 26 until 33 days of age, treatment ducks were provided one hour of misting with shed curtains closed in both treatment and control sheds. External health and welfare measures were taken directly on the ducks at 26 and 33 days of age, representing the start and end of the misting treatment period. Video recordings were also made of the control and treatment ducks one hour prior, one hour during, and one hour after the misting treatment across all sheds for all 8 days of the treatment period.

The results showed the misting application predominantly had impacts on the patterns of behavioural change across the treatment time periods between the misted and non-misted ducks rather than increasing or decreasing overall expression of specific behaviours. This may have in part been related to the curtain closure. There were also some differences between the treatment groups in feather cleanliness, but these may have been a result of pre-existing differences between sheds. The majority of welfare indicators showed no positive or negative effect of the misting treatment. These results indicate overhead misting does affect duck behaviour without compromising their welfare, but further research with larger water droplet sizes resulting in greater accumulation of surface water may have greater impact on the ducks. The baseline on-bird welfare measures provide data on how Australian birds fare compared to international published welfare metrics, including areas where improvements could be made.

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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 & Mench 2018). The most common ones for commercial meat production are Pekin, Muscovy and Mule (hybrid between the Pekin and Muscovy) ducks with varying prevalence depending on the global region (Babington & Campbell 2022; Karcher & Mench 2018). Similar to chicken meat production, grower meat ducks have fast growth rates and are slaughtered around 5 to 6 weeks 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 & Churchil 2022). Within the indoor housing, the birds are typically provided litter or raised plastic/wire flooring, nipple or bell drinkers, and food (Karcher & Mench 2018). However, domesticated ducks are semi-aquatic waterfowl and a major point of contention within the industry is the provision of bathing water (Babington & Campbell 2022). With global drives to improve welfare for livestock animals, bathing water provision in commercial grower duck production systems is a key target point for the industry's social licence to operate.

When water is available, domesticated ducks will engage in water-related behaviours 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; Liste et al. 2012b; O'Driscoll & Broom 2011; but see Schenk et al. 2016 for negative effects of water troughs on feather and eye condition). However, providing water to ducks on commercial farms is logistically challenging and may also have negative consequences for bird health. Bodies of water in commercial settings can become areas for bacterial contamination (Liste et al. 2012a), 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 & 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 impact 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 and it may also facilitate positive water-related experiences for the ducks but to date there is no verified method of water delivery that does not compromise bird health and/or system sustainability (see Babington & 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 UK standards recommending water for head dipping but only if it can be provided in a safe manner (Department of Environment Food and Rural Affairs UK (DEFRA) 2004). 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). Commercially, a greater proportion of the maximum number of ducks able to use a water resource was observed present at troughs, then large Plasson bell drinkers, then water nipples (Jones & Dawkins 2010b). These results suggest the water source need not be a standing body of water and that ducks will utilise the water resources that are additional to nipple drinkers. 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 (pers. comm. to D. L. M. Campbell, 2019). Water provision via misting application from 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 compromise on health and litter quality. Overhead sprinklers for surface wetting of commercial broilers for heat mitigation have been shown to be effective in alleviating heat stress and performance while utilising significantly less water than cooling pads (Liang et al. 2020).

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

Objectives

The original objectives of the research were to measure the environmental, behavioural, and welfare impacts of water provision via a misting system for commercial grower ducks. This was to be achieved via a combination of on-bird measurements, video recordings, farm production data, and environmental sensors.

The original hypothesis was that the provision of water via misting improves duck preening behaviour, feather, eye, and nostril health without decreasing environmental quality, foot and leg health.

The original objectives of the research were predominantly met with on-bird measurements of welfare made, video recordings of behaviour analysed, and the use of farm mortality records. Load-out weights were also obtained although they were only provided as a flock average. Environmental sensors recorded shed temperature and humidity but during the misting period the humidity sensors reached saturation, which affected subsequent readings.

Methodology

Ethical Statement

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

Commercial farms

The research was carried out on a single commercial Pekin duck grower farm (Cherry Valley strain) located in Victoria, Australia with Cohort 1 tested in May 2021 and Cohort 2 tested in November 2021. Four sheds (150 m L x 15 m W) were located adjacent to each other on the property. The sheds were open sided with curtains that could be raised up and down for ventilation purposes, with artificial fluorescent lighting as well as natural light. The system was floor-based with wood shavings as litter and each shed contained three rows of nipple drinkers and two rows of bell feeders along its length. The shed was exposed to ambient temperatures, which were (mean ± SEM) 20.08 ± 0.16°C across the study period (hours of observations only included: 11:00 to 14:00 daily) 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, UK) installed outside of two sheds and recording ambient conditions at 15-min intervals. The mean relative humidity during the treatment hours was 54.6 ± 1.0% for Cohort

1 and 44.14 ± 1.3% for Cohort 2. Prior to placement of birds, 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 a height of 1 m off the ground on one side, 15 m 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. 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; Gemini Data Loggers Ltd, West Sussex, UK) were attached to one of the feeder lines in the centre of the shed at bird height, recording ambient conditions at 15-min intervals during the observation period. For Cohort 1, on day 0 approximately 15,200 to 16,600 ducklings were placed into each of the four sheds (6.75–7.40 ducks/m^2) but in a staggered method, so that Shed A and Shed B (misted/non-misted respectively) were placed two days earlier than Sheds C and D (misted/non-misted respectively). For Cohort 2, approximately 12,500 ducklings were placed into each of three sheds (5.55 ducks/m^2) in a staggered method, so that Sheds A and B (misted/non-misted respectively) were placed one day earlier than Shed C (misted). Shed D was not used in the second cohort as the farm was placing fewer birds to meet reduced demand resulting from COVID-19. The ducklings were managed as per standard farm husbandry protocols with litter maintained daily (including litter top-up and rotation as needed). Reports from the farm staff indicated that similar litter management was applied across all sheds to maintain the litter quality.

Experimental protocol and data collection

The same protocols were applied for both Cohort 1 and Cohort 2 with a total of seven flocks included in the experiment (four misted treatment sheds, three non-misted treatment sheds). 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 day 26 and day 33. A sample of approximately 150 birds in total was corralled into a corner of the shed but the birds were captured in smaller groups of approximately 40–50 to minimise potential smothering and stress during the handling. During the first two scoring sessions, 200 ducks were captured until it was decided that 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 the 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 practised directly on sample ducks in the shed to ensure agreement on what was being observed. Following scoring, the ducks were placed back onto the ground to re-join the flock. Each small group of ducks was corralled from an area on the opposite side of the shed to minimise scoring the same birds, but this possibility was likely not eliminated. Due to the fixed position of the weighing set-up, 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 practised 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 (sheds were assessed in pairs based on staggered placement dates). From 11:00 until 14:00 the birds were left undisturbed by personnel for video recording across three hours (11:00 to 14:00). The misting system (1000 psi, nozzles 1 m apart spraying at a 45° angle) was turned on from 12:00 until 13:00 in the misting treatment shed, and the curtains were closed during this hour to better enable the water to accumulate and reach the birds. Researchers present on site confirmed the mist was accumulating on surfaces at duck level (i.e. feeder and drinker lines) during the hour of operation. The curtains were also closed during the same hour in the non-misted sheds. The misting system made a noise as it was running, audibly similar to the noise of the feeder line according to the researchers. 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. This video recording period encompassed one hour of video ‘prior’ to misting, one hour of video ‘during’ misting, and one hour of video ‘after’ misting. The same welfare scoring protocols were carried out across Sheds C and D when they reached 26 days of age. Daily misting occurred at the same time until 33 days 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. 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. 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 short periods of time (approximately 5 mins) during the observation period to reduce shed temperature in the non-misting shed (these data were removed from the behavioural analyses).

Daily mortality and culls across the trial period were recorded by the farm staff as well as average load-out weight when the birds were removed for processing.

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

Indicator	Score	Description
Feather quality (neck, wings, back, rump)	1	Damaged feathers (worn/deformed/missing) with areas < 5 cm in diameter at the largest point
	2	Damaged feathers (worn/deformed/missing) with areas ≥ 5 cm in diameter at the largest point
Feather cleanliness (neck, wings, back, rump)	1	Staining/discolouration on feathers < 5 cm in diameter at its largest; includes staining from blood
	2	Staining/discolouration 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

During the TW, feather quality and cleanliness were combined into a single category per duck region.
Y/N = Yes/No.

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 behaviours were less reliable between observers and thus were later categorised together as ‘other’ and not statistically analysed (see *Data and Statistical Analyses* section). Video recordings from four cameras within each shed (total of 16 cameras) across eight days (day 26 to day 33) were decoded across a 3-hr period that encompassed one hour prior to misting, one hour during, and one hour after, with the same hours observed in the non-misted sheds. Point observations were made every 10 mins by watching across a 5-sec video clip to confirm the behaviour 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 their body within the frame was not included) were first counted to then calculate the proportions of ducks performing each behaviour. The behaviours observed are listed in Table 2. In total n = 2393 datapoints were recorded per behaviour for Cohort 1 (19 observations points x 8 days x 4 cameras x 4 sheds minus 39 missing data points due to video system failure), and n = 1805 per behaviour for Cohort 2 (19 observations points x 8 days x 4 cameras x 3 sheds minus 19 observation points where one camera failed to record on day 32 in Shed A).

Table 2 Ethogram of the behaviours recorded during video observations of the ducks

Behaviour	Description
Allopreening	Duck uses its bill to preen another duck without it moving away
Body shaking	Duck shakes its whole body
Conspecific dabbling	Duck dabbles at another duck with its beak causing it to move away
Drinking	Duck has beak 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 its wings simultaneously

Data and Statistical Analyses

All analyses were conducted in JMP® 16.1.0 (SAS Institute, Cary, NC, USA) with α set at 0.05.

The temperature data were compiled for the 3-hr observation period of each day both inside the shed and outside the shed. Readings across the multiple sensors in each location (2 x sensors outside, 3 x sensors per shed inside) were averaged to provide one mean value per 15 mins (total dataset n = 672: 12 readings x 8 days x 7 sheds) representing inside and outside temperatures. 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 days earlier than Sheds C and D; Sheds A and B in Cohort 2 started 1 day earlier than Shed C). The temperature data were visually displayed, but no statistical analyses were conducted. The humidity data in the misted sheds showed saturation (100% humidity) during the misting period, which then resulted in subsequent false readings with some of the sensors (i.e. from 100% humidity to 0% humidity 15 mins afterwards) and thus these data were not analysed further.

The scores from the catch-and-inspect sampling were compiled per individual duck across age (26 or 33 days) per shed for misted and non-misted treatments. The final dataset comprised n = 1253 ducks for the misted treatment and n = 959 ducks for the non-misted treatment across both cohorts. Individual body weight data were analysed using a General Linear Mixed Model (GLMM) comparing the fixed effects of age and treatment, and included the random effects of ‘shed’ and ‘cohort’.

Restricted maximum likelihood (REML) estimation methods were applied. Where significant differences were present, post-hoc Student's t-tests were conducted on the least squares means. Only 3 ducks were observed with eye issues (score 1) and no ducks were observed with hock issues, so these data were not analysed further. Similarly, only 4 ducks were recorded with feather quality or cleanliness issues on the neck (scores 1 and 2), only 3 ducks with poor feather quality on the chest (scores 1 and 2), only 2 ducks with poor feather quality on the rump (scores 1 and 2) at 26 days of age (more ducks observed at 33 days of age), and only 6 ducks with feather cleanliness issues on the rump (score 1) at 26 days of age; thus these datasets were removed from analyses. All other welfare indicators were analysed using multiple Pearson's chi-square tests to compare the effect of treatment at 26 and 33 days of age separately, blocking for the effect of 'shed'.

The total number of birds recorded with some form of damage during the transect walks were summarised per shed. The proportion of ducks displaying specific welfare indicators was calculated as the proportion of the total number of observed ducks with damage, and not the proportion of the total number of ducks in the shed. Proportions were calculated per transect walk per shed both at the start (26 days), and at the end (33 days) of the misting period across both cohorts (total dataset n = 56 per welfare indicator: 4 transect walks x 7 sheds x 2 time periods). These data were analysed 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-day misting period.

The average load-out weight data were compiled per each of the 7 sheds within the study. Some sheds were emptied out over multiple days (2 to 3) and thus there were a total of 11 load-out weights recorded for the 7 sheds. Ducks that were removed at 34 to 36 days of age showed heavier weights that increased as the ducks aged. These mean weight values are summarised per treatment but were not statistically analysed due to the low sample size. 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 days x 7 sheds). These data were not normally distributed and were analysed via a Wilcoxon signed-rank test to compare the effect of the misting treatment.

The behavioural observation data were converted into proportions of the total ducks observed within the video frame performing each behaviour. The proportions were then compiled per each of the 15 behaviours for each time point in each shed across both cohorts, totalling a final dataset of n = 4198 per behaviour. The behaviours of 'allopreening', 'body shaking', 'conspecific dabbling', 'wing flapping', 'environmental pecking' and 'scratching' were observed infrequently and were combined into a single category of 'other' presenting graphically but with no statistical analyses conducted. The two days of higher temperatures in Cohort 2 were removed from the final dataset and then each observation time point was averaged across the 8 days of the trial period. Thus, the final behavioural dataset consisted of n = 532 (19 observation points x 4 cameras x 7 sheds) per each behaviour of 'drinking', 'panting', 'preening', 'rooting litter', 'sitting', 'standing', 'stretching', 'tail wagging', and 'walking'. Behavioural data except for 'sitting' had a constant of 0.00001 added to account for values of '0' and were logit-transformed before analysing separately using GLMMs with the fixed effects of treatment (misted, non-misted), treatment time (prior, during, after) and their interaction and random effects of 'time' nested within treatment time, 'shed' nested with cohort, 'camera' nested within shed and cohort, and 'cohort'. Restricted maximum likelihood (REML) estimation methods were applied. The studentised residuals were inspected for visual homoscedasticity and Tukey's HSD tests were applied to the least squares means when significant differences were present.

Results

Environmental

Figure 1 shows the ambient outside and inside shed temperatures across the 8-day trial period for the misted and non-misted sheds in Cohort 1 and Cohort 2. The ambient temperatures were cooler in Cohort 1 than Cohort 2 based on differing seasons (autumn versus spring respectively). Generally, temperatures were cooler inside the sheds than ambient temperatures outside, except for higher heat inside the shed during the misting period in Cohort 1 for the non-misted sheds when curtains were closed (Figure 1). The misted shed remained cooler when the curtains were closed due to the water application.

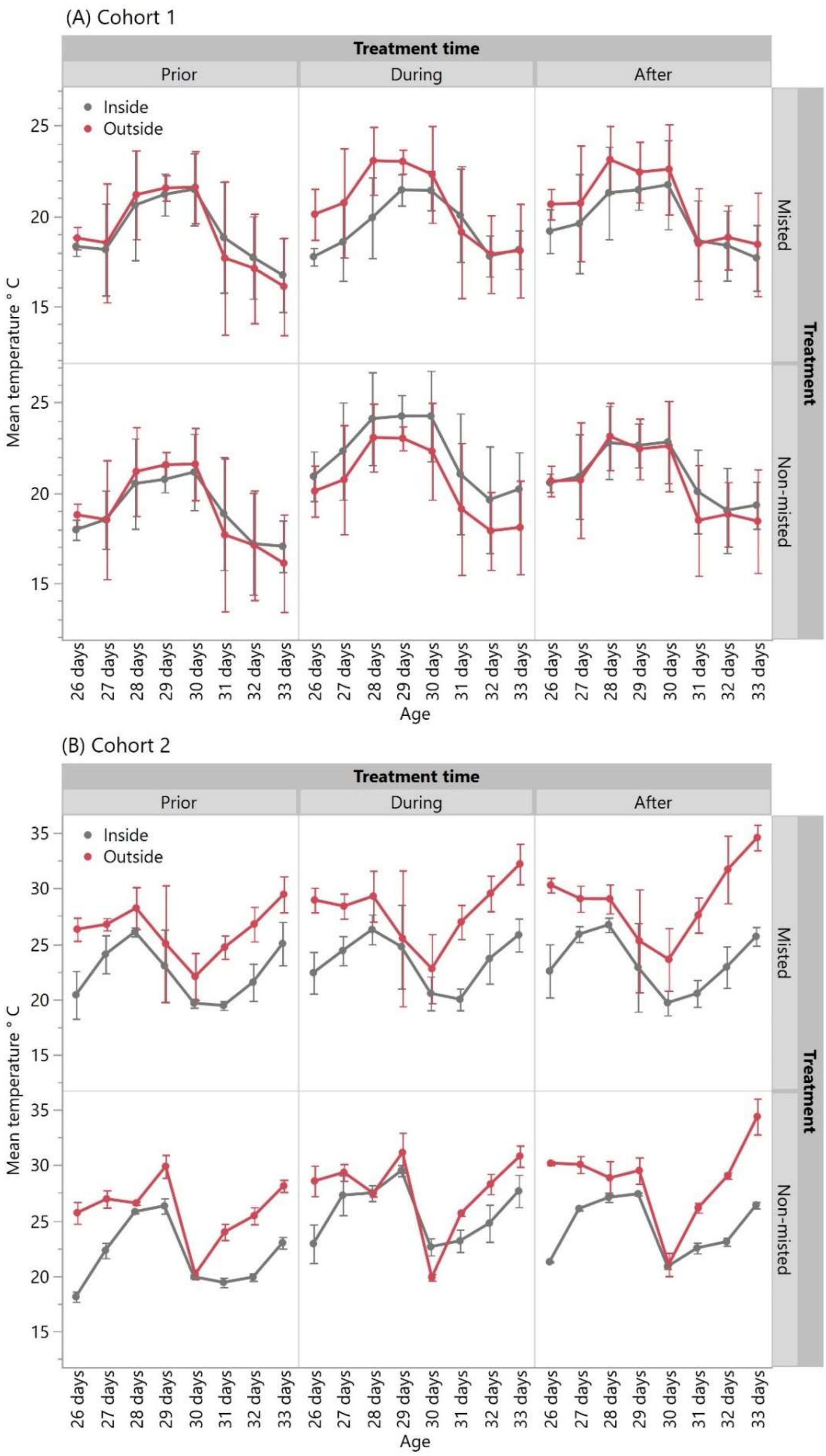

Figure 1 The mean (± SD) ambient outside and inside shed temperature across duck age prior to, during, and after a misting treatment for both misted and non-misted (control) sheds for Cohort 1 (A) and Cohort 2 (B)

Note the different scales in the Y-axis between the two cohorts.

Welfare indicators

There was a significant interaction between treatment and age for body weight ($F_{1,2206}$ = 24.27, P < 0.0001) but this was due to the misted ducks showing a lower body weight than the non-misted ducks at the beginning of the treatment period (LSM ± SEM misted at 26 days: 217.3 ± 9.5 g; non-misted at 26 days: 223.8 ± 9.6 g; misted at 33 days: 299.6 ± 9.6 g; non-misted at 33 days: 297.7 ± 9.6 g). Table 3 displays the Pearson's chi-squared test results for the effect of misting treatment for welfare indicators assessed during catch-and-inspect. At 26 days, at the start of the treatment period, there were significant differences in feather cleanliness on the chest (P < 0.0001), significant differences in footpad dermatitis (P = 0.0005) and trends for significant differences in feather quality on the back (P = 0.08), feather quality on the wings (P = 0.08) and presence of blood (P = 0.08, Table 3). At 33 days 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 non-misted 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 non-misted 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 non-misted ducks at 33 days of age (P < 0.001, Table 3). The most prevalent welfare indicators observed were nostril cleanliness, footpad dermatitis, cleanliness of the chest, back, and wing feathers, and the presence of blood.

Table 3 The percentage of the scored ducks within both treatment groups (misted, non-misted) that showed the presence of a specific welfare indicator at 26 and 33 days of age, representing the start and end of the misting treatment period respectively

Welfare indicator	Age (days)	Treatment	Percentage	Test statistics
Nostrils – 1	26	Misted	40.0	χ^2 = 1.63, df = 2,
Nostrils – 2	26	Misted	1.5	n = 1161,
Nostrils – 1	26	Non-misted	39	P = 0.44
Nostrils – 2	26	Non-misted	2.5	
Nostrils – 1	33	Misted	43.2	χ^2 = 0.46, df = 2,
Nostrils – 2	33	Misted	5.0	n = 1051,
Nostrils – 1	33	Non-misted	45.2	P = 0.80
Nostrils – 2	33	Non-misted	4.7	
FC Chest – 1	26	Misted	34.5	χ^2 = 31.12, df = 2,
FC Chest – 2	26	Misted	55.0	n = 1161,
FC Chest – 1	26	Non-misted	29.5	***P* < 0.0001**
FC Chest – 2	26	Non-misted	67.1	
FC Chest – 1	33	Misted	23.5	χ^2 = 0.07, df = 2,
FC Chest – 2	33	Misted	68.0	n = 1051,
FC Chest – 1	33	Non-misted	22.8	P = 0.97
FC Chest – 2	33	Non-misted	68.7	
FQ Back – 1	26	Misted	2.0	χ^2 = 5.06, df = 2,
FQ Back – 2	26	Misted	0.6	n = 1161,
FQ Back – 1	26	Non-misted	1.0	P = 0.08
FQ Back – 2	26	Non-misted	0	
FQ Back – 1	33	Misted	0.7	χ^2 = 18.2, df = 2,
FQ Back – 2	33	Misted	1.0	n = 1051,
FQ Back – 1	33	Non-misted	3.6	***P* = 0.0001**
FQ Back – 2	33	Non-misted	3.1	

FC Back – 1	26	Misted	22.8	χ^2 = 0.93, df = 2,
FC Back – 2	26	Misted	5.8	n = 1161,
FC Back – 1	26	Non-misted	20.5	*P* = 0.63
FC Back – 2	26	Non-misted	5.9	
FC Back – 1	33	Misted	33.2	χ^2 = 55.3, df = 2,
FC Back – 2	33	Misted	5.7	n = 1051,
FC Back – 1	33	Non-misted	14.6	***P* < 0.0001**
FC Back – 2	33	Non-misted	3.6	
FQ Wing – 1	26	Misted	3.2	χ^2 = 3.3, df = 2,
FQ Wing – 1	26	Non-misted	1.6	n = 1051, *P* = 0.08
FQ Wing – 1	33	Misted	3.0	χ^2 = 8.57, df = 2,
FQ Wing – 2	33	Misted	1.2	n = 1051,
FQ Wing – 1	33	Non-misted	4.9	***P* = 0.01**
FQ Wing – 2	33	Non-misted	3.3	
FC Wing – 1	26	Misted	19.5	χ^2 = 0.2, df = 2,
FC Wing – 2	26	Misted	0.5	n = 1161,
FC Wing – 1	26	Non-misted	18.5	*P* = 0.91
FC Wing – 2	26	Non-misted	0.4	
FC Wing – 1	33	Misted	46.5	χ^2 = 33.9, df = 2,
FC Wing – 2	33	Misted	6.5	n = 1051,
FC Wing – 1	33	Non-misted	31.9	***P* < 0.0001**
FC Wing – 2	33	Non-misted	3.3	
FQ Rump – 1	33	Misted	4.8	χ^2 = 2.71, df = 2,
FQ Rump – 2	33	Misted	1.8	n = 1051,
FQ Rump – 1	33	Non-misted	3.1	*P* = 0.26
FQ Rump – 2	33	Non-misted	2.7	
Inversion rubbing	26	Misted	2.0	χ^2 = 2.6, df = 2,
Inversion rubbing	26	Non-misted	1.6	n = 1161, *P* = 0.27
Inversion rubbing	33	Misted	2.2	χ^2 = 0.27, df = 2,
Inversion rubbing	33	Non-misted	2.7	n = 1051, *P* = 0.60
Blood (Y)	26	Misted	45.5	χ^2 = 3.06, df = 2,
Blood (Y)	26	Non-misted	40.3	n = 1161, *P* = 0.08
Blood (Y)	33	Misted	53.8	χ^2 = 17.5, df = 2,
Blood (Y)	33	Non-misted	40.8	n = 1051, ***P* < 0.001**
Footpad – 1	26	Misted	75.04	χ^2 = 11.97, df = 2,
Footpad – 1	26	Non-misted	65.75	n = 1161,
				***P* = 0.0005**
Footpad – 1	33	Misted	68.0	χ^2 = 2.38, df = 2,
Footpad – 2	33	Misted	0.50	n = 1051, *P* = 0.30
Footpad – 1	33	Non-misted	69.0	
Footpad – 2	33	Non-misted	1.33	

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.

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

Table 4 The mean (±SEM) percentages of total observed ducks with damage showing each specific welfare indicator

Treatment	Time period	Welfare indicator: 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
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
Non-misted	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
Non-misted	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

Values are presented for misted and non-misted treatment sheds at the start of the misting treatment period (26 days of age) and at the end of the misting treatment period (33 days of age) across the two cohorts.
Q/C = Quality/cleanliness.
Summed proportional values across rows are greater than 1 as individual ducks may have presented more than one welfare indicator.
See Table 1 for a full description of the welfare indicators.

There was no significant difference in the total mortality across the trial period between the misted and non-misted sheds ($\chi2 = 0.91$, df = 1, $P = 0.34$) and overall mortality was low across all sheds (Figure 2). The mean (± SEM) load-out weight for misted sheds at 34 days was 2.80 ± 0.03 kg, at 35 days was 2.84 ± 0.04 kg, and at 36 days was 3.03 kg with the mean load-out weight for non-misted sheds at 35 days being 2.83 ± 0.08 kg.

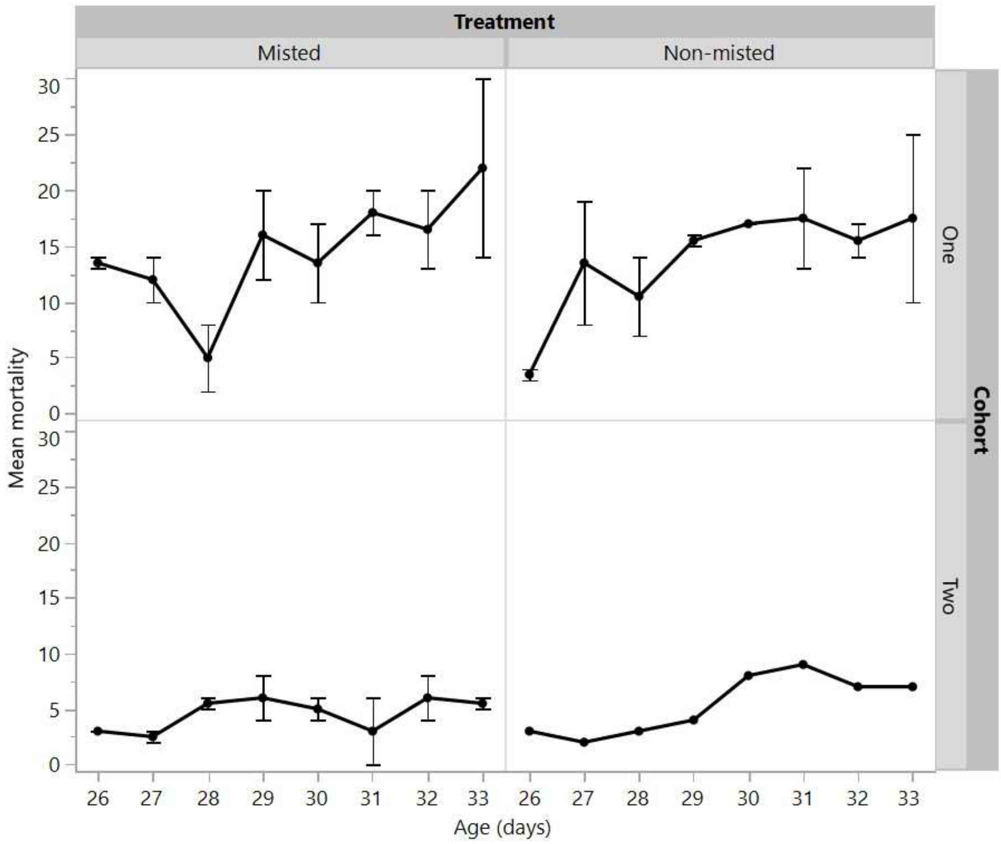

Figure 2 Daily mean (±SEM) mortality during the trial period (26 to 33 days of age) for misted and non-misted sheds across the two cohorts

Behaviours

Figure 3 displays the proportions of ducks exhibiting each behaviour across both cohorts for the misted and non-misted treatment groups, prior to, during, and after the misting period. The most prevalent behaviour observed was ducks sitting down on the litter resting, which occupied the majority of the observations, followed by drinking, panting, and preening in similar proportions.

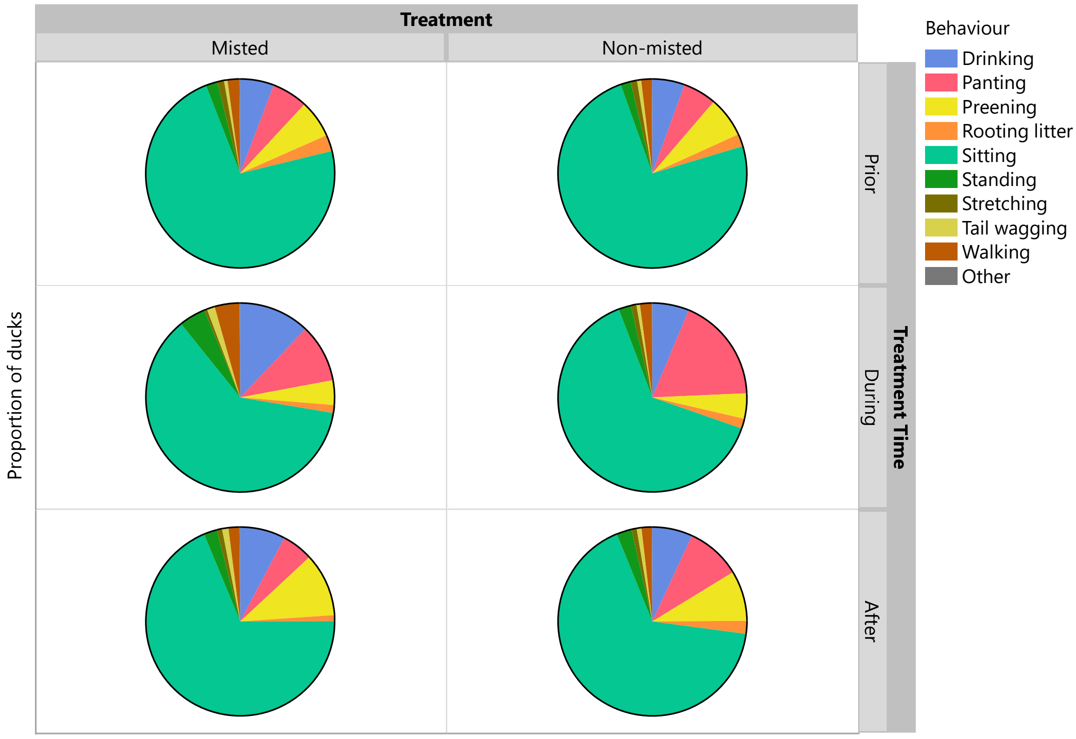

Figure 3 The proportion of observed ducks exhibiting each behaviour across misted and non-misted treatment groups, prior to, during, and after the misting treatment

'Other' included the behaviours of allopreening, body shaking, dabbling conspecifics, environmental pecking, scratching, and wing-flapping.

Analyses showed that there was a significant interaction between treatment and treatment time for the proportion of ducks drinking ($F_{2,497.7} = 29.76$, $P < 0.0001$), with misted ducks showing more drinking than non-misted ducks during the misting period (Table 5). The misted ducks showed more drinking during and after misting relative to their drinking prior, whereas the non-misted ducks showed their most drinking after the misting period (Table 5). There was also a significant effect of treatment time ($F_{2,431.5} = 5.14$, $P = 0.006$) with more drinking after the misting period than prior or during. There was no overall effect of treatment ($F_{1,4.47} = 1.85$, $P = 0.24$).

There was a significant interaction between treatment and treatment time for the proportion of ducks panting ($F_{2,496.8} = 14.97$, $P < 0.0001$), with the non-misted ducks showing an increase in panting during the misting period (when the curtains were closed) (Table 5). There was also a significant effect of treatment time ($F_{2,33.33} = 9.24$, $P = 0.0006$) with less panting prior, than during treatment. There was also an overall significant effect of treatment with more panting in the non-misted ducks ($F_{1,4.0} = 9.55$, $P = 0.04$).

There was a significant interaction between treatment and treatment time for the proportion of ducks preening ($F_{2,495.4}$ = 10.06, P < 0.0001), with the misted ducks showing their least preening during the misting period and their most preening after the misting period (Table 5). The non-misted ducks showed similar preening prior and during the misting period, and the most preening after the misting period. The misted ducks showed less preening than the non-misted ducks during misting. There was also a significant effect of treatment time ($F_{2,314.3}$ = 42.95, P < 0.0001), with more preening after the misting period and the least preening during misting. There was only a trend for an overall effect of treatment ($F_{1,4.07}$ = 5.32, P = 0.08).

There was a significant interaction between treatment and treatment time for the proportion of ducks rooting in the litter ($F_{2,501.2}$ = 21.64, P < 0.0001). The misted ducks showed their most rooting in the litter prior to the misting period whereas the non-misted ducks showed similar proportions across all treatment time periods (Table 5). There was also a significant effect of treatment time ($F_{2,153.4}$ = 7.81, P = 0.0006), with the most rooting in the litter shown prior to misting. There was no overall effect of treatment ($F_{1,3.95}$ = 4.40, P = 0.10).

There was a significant interaction between treatment and treatment time for the proportion of ducks sitting ($F_{2,497.6}$ = 5.89, P = 0.003), with the both the misted and non-misted ducks showing their most sitting prior to the misting treatment and the least after the misting treatment, with the misted ducks showing a greater reduction in sitting during the misting treatment (Table 5). There was also a significant effect of treatment time ($F_{2,480.3}$ = 35.45, P < 0.0001) with the most sitting prior to the treatment. There was no overall effect of treatment ($F_{1,3.97}$ = 0.18, P = 0.69).

There was a significant interaction between treatment and treatment time for the proportion of ducks standing ($F_{2,498}$ = 23.07, P < 0.0001), with the non-misted ducks showing their least standing during the misting period (Table 5). There was no overall significant effect of treatment time ($F_{2,301.2}$ = 1.56, P = 0.21) or treatment ($F_{1,5.14}$ = 0.18, P = 0.70).

There was a significant interaction between treatment and treatment time for the proportion of ducks stretching ($F_{2,496.5}$ = 6.89, P = 0.001), with the non-misted ducks showing more stretching during the misting period than the misted ducks (Table 5). There was no overall significant effect of treatment time ($F_{2,81.12}$ = 2.08, P = 0.13) but there was an overall significant effect of treatment, with more stretching observed in the non-misted ducks ($F_{1,3.13}$ = 34.40, P = 0.009).

There was a significant interaction between treatment and treatment time for the proportion of ducks showing tail wagging ($F_{2,497.3}$ = 13.98, P < 0.0001), with the misted ducks showing more tail-wagging during the misting period relative to prior, whereas the non-misted ducks showed similar proportions across all treatment time periods (Table 5). There was no overall significant effect of treatment time ($F_{2,10.93}$ = 0.66, P = 0.53) or treatment ($F_{1,4.30}$ = 0.13, P = 0.73).

There was a significant interaction between treatment and treatment time for the proportion of ducks walking ($F_{2,501.4}$ = 13.19, 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 ($F_{2,274.7}$ = 1.77, P = 0.17) or treatment ($F_{1,4.06}$ = 0.44, P = 0.54).

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

		Treatment time		
Treatment	**Behaviour**	**Prior**	**During**	**After**
Misted	Drinking	0.07 ± 0.009^{bd}	0.14 ± 0.006^{ac}	0.14 ± 0.01^{ac}
Non-misted		0.07 ± 0.01^{cd}	0.07 ± 0.009^{d}	0.13 ± 0.01^{ab}
Misted	Panting	0.06 ± 0.04^{bc}	0.07 ± 0.03^{bc}	0.07 ± 0.04^{c}
Non-misted		0.07 ± 0.04^{bc}	0.17 ± 0.03^{a}	0.11 ± 0.04^{ab}
Misted	Preening	0.05 ± 0.009^{b}	0.03 ± 0.006^{c}	0.18 ± 0.01^{a}
Non-misted		0.06 ± 0.009^{b}	0.04 ± 0.006^{b}	0.16 ± 0.01^{a}
Misted	Rooting litter	0.03 ± 0.005^{a}	0.02 ± 0.003^{bc}	0.01 ± 0.006^{c}
Non-misted		0.03 ± 0.005^{ab}	0.02 ± 0.004^{bc}	0.03 ± 0.006^{ab}
Misted	Sitting	0.71 ± 0.05^{ab}	0.61 ± 0.05^{cd}	0.49 ± 0.05^{e}
Non-misted		0.70 ± 0.05^{ac}	0.63 ± 0.05^{bd}	0.46 ± 0.05^{e}
Misted	Standing	0.03 ± 0.004^{ab}	0.05 ± 0.002^{a}	0.04 ± 0.006^{ab}
Non-misted		0.03 ± 0.005^{a}	0.02 ± 0.002^{b}	0.04 ± 0.006^{a}
Misted	Stretching	0.006 ± 0.002^{abc}	0.004 ± 0.001^{c}	0.004 ± 0.003^{bc}
Non-misted		0.005 ± 0.002^{ab}	0.009 ± 0.001^{a}	0.004 ± 0.003^{abc}
Misted	Tail wagging	0.006 ± 0.004^{b}	0.02 ± 0.004^{a}	0.01 ± 0.004^{ab}
Non-misted		0.007 ± 0.004^{ab}	0.005 ± 0.004^{ab}	0.01 ± 0.004^{ab}
Misted	Walking	0.02 ± 0.007^{b}	0.05 ± 0.006^{a}	0.03 ± 0.008^{ab}
Non-misted		0.02 ± 0.008^{ab}	0.02 ± 0.007^{b}	0.04 ± 0.009^{ab}

$^{a–e}$ Dissimilar superscript letters indicate differences in the means across the treatment time for both treatment groups. Analyses were conducted on logit-transformed proportions with a constant of 0.00001 added to accommodate values of '0' for all behaviours except 'sitting'.

Discussion

This study was carried out to determine if the application of overhead misting to commercial grower ducks for a sustained period of time would be an effective method of water delivery to wet the ducks and facilitate behaviour and welfare improvements without significant welfare compromises. The results showed that the misting application predominantly had impacts on the patterns of behavioural change across the treatment time periods between the misted and non-misted ducks rather than increasing or decreasing overall expression of specific behaviours. There were also some differences between the treatment groups in feather cleanliness, but these may have been a result of litter management differences or pre-existing differences between sheds. The majority of welfare indicators showed no positive or negative effect of the misting treatment. These results indicate overhead misting does have some effects on duck behaviour without compromising their welfare, but further research with larger water droplet sizes resulting in greater accumulation of surface water may have greater impact on the ducks.

The welfare measures applied to samples of individual ducks as well as across the whole shed found few differences in welfare indicators between the misted and non-misted treatment sheds. The improved chest feather cleanliness in the misted ducks may have been a result of increased litter management to compensate for the additional water that was added during the misting period. More ducks were observed with feather cleanliness rather than feather quality issues, and this was primarily related to the blood from damaged pin/blood feathers which discoloured the feathers. While the ducks in the misted sheds presented poorer feather cleanliness on the wings and back, there was also a trend for significantly more blood in the initial scores before the treatment period commenced, indicating that there were some inherent shed/flock differences in the presence of this welfare indicator. Presence of blood from the pin feathers was prevalent across all ducks detected in both the transect walks and catch-and-inspect methods, and has previously been reported to be one of the most common welfare indicators in commercial Pekin duck flocks assessed in the United States via the catch-and-inspect method (Abdelfattah et al. 2020). 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 and growth rates. 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 classified as a welfare indicator 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. 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.

The misting application had impact on observed behaviours, but this was through changes in the behavioural patterns that the misted and non-misted groups exhibited across the periods prior to, during, and after the misting application rather than affecting overall proportions of the observed behaviours. There was more panting overall in the non-misted ducks but that was likely a result of the increased shed temperatures when the curtains were closed for the corresponding misting hour in the treatment sheds. The changes in behaviour across time in the non-misted ducks was likely affected by the closure of the curtains, which was applied to control for necessary corresponding closures in the treatment sheds. Further testing in enclosed sheds where there would be minimal change in environmental conditions across control sheds relative to treatment sheds may show limited changes across time in ducks without any misting treatment applied. Conversely, these differences may have captured typical variation across the hours of the day in the ducks' behavioural expression.

When the misting system started operating, the treatment ducks showed increases in their drinking. This was not predicted, and it is uncertain if the water application itself stimulated the birds to seek out a water source, 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. Further studies controlling for the noise of the misting line would be needed to confirm this. 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 non-misted ducks also showed more preening afterwards, but the misted ducks showed a greater increase between during and after periods. The misted ducks may have shown less preening during the hour of misting as they were occupied with other behaviours 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 behaviour. The increases in standing and 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 behaviour when wetted. The increase in activity may have other positive benefits on duck health where previous research showed poorer gait resulted in more panting, less time at the drinkers, and more time resting (Jones & 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 welfare concern.

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 one hour 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 time, occurring at a different time of day, or at multiple points within the 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. 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 on the developing birds. The differences in duck behaviour were also subtle, suggesting that genetic selection for fast growth rates may be the primary driver of the behavioural patterns observed where birds will still spend the majority of their time resting on the litter. 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. Overall system sustainability must still be considered when striving to reach a solution on a commercial level for providing water to ducks.

Implications

This research provides evidence of the impacts of high pressure misting for surface wetting of grower ducks. The research shows that the misting can affect patterns of behaviour in the ducks without compromising their welfare but does not increase overall behavioural expression. Misting for a longer period of time, or lower pressure misting with greater bird saturation may have more significant effects. The research is being prepared for peer-reviewed publication and the results have been communicated directly to industry via a face-to-face meeting. Specific resulting implications from the misting treatment and objective welfare assessments are listed below:

- There were diurnal or daily patterns of preening behaviour independent of the misting or control treatments.
- Approximately 3–6% of ducks exhibited preening between 11am and 1pm, which increased up to 18% between 1pm and 2pm, corresponding to the ‘post misting’ phase.
- The misting treatment stimulated additional drinking and tail wagging that may be viewed as an improved behavioural repertoire, but the drinking may have been associated with the noise of the misting lines running.
- There was almost no evidence of poor eye condition and a range of about 1.5% to 5% of ducks with significant nostril occlusion.
- Plumage cleanliness seems to be significantly influenced by the presence of blood on the plumage and the incidence appears to range from 40–50% of sampled ducks.
- The blood contamination may have been influenced by the pin feather development as picking behaviour was not seen during the video observations; however, picking may have occurred at an earlier age.

- Severe footpad dermatitis was at a low incidence (0.5–1.33%) and did not appear to be influenced by the misting treatment.

Recommendations

Misting application does appear to have positive effects on duck behaviour without negative effects on bird welfare when accompanied by appropriate litter management, but the behavioural differences are small. Further research should seek to understand if lower pressure misting with increased bird saturation would have more substantial impacts, and what the effects of different schedules of misting application such as multiple misting periods across the day, or increased duration of misting would be on duck behaviour and welfare. The welfare measures demonstrated how ducks in these Australian sheds compared with international published measures. Specific points for future work are listed below:

- The pattern of preening behaviour during the day needs more analysis in commercial duck sheds, and a realistic standard or expectation for this behaviour needs to be defined.
- Some understanding of plumage wetness may assist in guiding further experimentation with droplet size and misting duration in relationship to preening behaviours.
- Some previous research in the UK indicates that preening behaviours increase significantly after 3 weeks of age. Research models could be developed that examine this period as a mechanism to train ducks to augment the behaviour, or understand the limitations in behavioural development for fast-growing ducks to set realistic behavioural expectations.
- More analysis of pin feather development is required to investigate the variation in the extent of the blood leakage onto plumage and strategies for resolving this (e.g. stocking density and/or nutrition).
- Observations of behaviour across the growth cycle may clarify if the ducks are exhibiting picking behaviour.
- Considerations could be made for top dressing of shed litter and any implications for nostril contamination.
- Nostril contamination may have some relationship to shed humidity and perhaps seasonal conditions.

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Media and Publications

There is currently one publication submitted to *Journal of Animal Science* for peer review.

Intellectual Property or Confidential Information Arising

N/A

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