Poultry Science

Visual access to an outdoor range early in life, but not environmental complexity, increases meat chicken ranging behavior

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ABSTRACT Not all chickens access an outdoor range when the opportunity is provided. This may be related to the abrupt change in environments from the stable rearing conditions to the complexity of the outdoor range. We aimed to prepare chickens to range by increasing the complexity of the indoor environment early in life with the intention to encourage range use. Mixed sex Cobb500 chickens were allocated to 1 of 3 treatment groups: visual access (**VA**) treatment provided VA to the outdoor range from day old via transparent pop-hole covers; environmental complexity (**EC**) treatment provided an artificial haybale, fan with streamers and a solid vertical barrier; Control treatment was a representative conventional environment. Chickens were given access to the outdoor range at 21 d of age. Behavior in the home pen was assessed in wk 1, 2 and 5 and individual ranging behavior was monitored through radio frequency identification (**RFID**) technology. The VA chickens were more active compared to EC ($P = 0.006$) and Control ($P = 0.007$) chickens and spent more time foraging than control chickens ($P = 0.036$) during the first week of life. More VA chickens accessed the range area compared to EC chickens ($P = 0.015$). VA chickens accessed the range sooner after they were first provided access and spent more time on the range than EC and control chickens ($P < 0.001$). Mortality was lower in the VA treatment compared to EC ($P = 0.024$) and control group ($P = 0.002$). There was evidence that VA chickens weighed less than Control and EC chickens, however results were inconsistent between age and sex. Hence, providing meat chickens with VA to an outdoor range early in life increased activity in early life, decreased latency to first access the range and increased time on the range and lowered mortality. Future work should aim to understand the mechanism behind these changes in behavior to develop recommendations for producers to implement in commercial conditions.

Key words: activity, environmental enrichment, rearing, free-range, natural light

2023 Poultry Science 102:103079
https://doi.org/10.1016/j.psj.2023.103079

INTRODUCTION

Meat chickens on free-range commercial farms take an average of 3 to 5 d to access the range after pop-holes first open (Taylor et al., 2017). This lag to access the range may be related to the contrast between the simple indoor rearing environment and the complex range environment and the abrupt manner in which the range area is first provided. As latency to range has been associated with overall use of the outdoor range in meat chickens (Taylor et al., 2017; Taylor et al., 2020), reducing the latency for chickens to access an outdoor range may encourage greater range use, including number of chickens on the range and distance ranged from the shed. Preparing the chickens to range, by appropriate and practical rearing experiences, could enhance use of the outdoor range. Indeed, Gordon and Forbes (2002) found that alterations to the indoor rearing environment increased ranging behavior later in life, surpassing the effects of providing shelters on the range. However, Gordon and Forbes (2002) could not determine the resource

Received June 13, 2023.
Accepted August 25, 2023.

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characteristics that were responsible for the increase in range use or the impact on chicken welfare and productivity. There is a need to understand the potential of modified indoor rearing environments to improve chicken ranging behavior, productivity, and welfare.

The provision of panels and perches to increase environmental complexity (**EC**) has been shown to have some effect on the use of an outdoor range. Rodriguez-Aurrekoetxea et al. (2014) showed that meat chickens ranged further when they were provided with panels and perches, although range use reported in the study was relatively low across all treatment groups—an average of 63% of birds across treatments never accessed the outdoor range. However, vertical panels have also been shown to influence the use of space inside the home pen, as meat chickens that were provided with vertical panels were more likely to utilise the central area of an indoor pen compared to chickens in a less complex envrionment (Cornetto and Estevez, 2001). Complex envrionments affect other aspects of meat chicken behaviour and welfare, such as reducing anxiety (Anderson et al., 2021b) and increasing optimisim (positive mood; (Anderson et al., 2021a)), agency (Špinka, 2019) and activity (Bizeray et al., 2002a) all of which may be important chicken characteristics for range use. Evidence from laying hens suggest that EC (specifically novelty in the rearing envrionment) does not increase range use but does increase inquisitive curiosity (Taylor et al., 2023). The proportion of time spent contra freeloading prior to range access (which may be a proxy for curiosity) has been shown to be associated with range use (Ferreira et al., 2021) yet, to the authors knowledge, the link between a complex environment, curiosity and range use in meat chickens has not been assessed. It may be important to ensure that the characteristics of items provided in complex environments are chosen based on the desired outcome. For example, items that increase curiosity or spatial memory to improve range use. It should also be noted that, the impact of 'complex envrionments' may be associated with only 1 or 2 of the resources rather than complexity per se.

The objectives of this experiment were to increase ranging behavior by increasing the complexity of the indoor rearing environment. Items chosen to increase the complexity of the rearing environment were chosen based on the potential impact on chick development and characteristics such as spatial memory (Ferreira et al., 2019; Ferreira et al., 2020), object permeance (Vallortigara, 2006), adaptation to novelty (Altan et al., 2013), and curiosity (Taylor et al., 2023) which were hypothesized to be associated with range use. We aimed to determine the impact of early life experience on the latency to range, the number of chickens that access the range, the time an individual spent on the range and the distance ranged from the shed, as well as productivity outcomes. We hypothesized that altering the meat chicken indoor rearing environment would be associated with increased ranging behavior, such as reduced latency to first access the range, more chickens on the range, more time spent on the range and more chickens ranging further from the shed.

MATERIALS AND METHODS

Animals and Housing

This experiment was approved by the UNE animal ethics committee (AEC20-034) and was conducted at the UNE Laureldale free-range research facility (Armidale, NSW, Australia).

Mixed sex Cobb500 day old chicks (n = 450) were housed in groups of 25 across 18 pens (6.3 × 1.6 m; maximum stocking density of 9.7 kg/m^2 at 42 d of age) with 6 pen replicates per treatment; see supplementary material for shed layout and distribution of replicates across pens). Each pen had 7 to 10 cm of dry wood shaving litter, a circular feeder (30 cm diameter) with ad libitum feed (starter 0−8 d; grower 8−28 d; finisher; 28−42 d; Barastock, Ridley, Melbourne, VIC, Australia). Chicks were weighed on arrival and given a unique identification wing band (Eadies Bros., & Co. Ltd., Selkirk, Scottish Borders, UK). The shed was mechanically ventilated (Big Dutchman, Qld, Australia), and heat provided by electrical brooders (Science Engineering Workshop, UNE, Armidale, Australia).

Experimental Treatments

On arrival, day old chicks were randomly allocated to one of the following treatment groups: visual access (**VA**), Envrionmental Complexity (**EC**), or control (**CON**). Treatments were applied from d 1 until 42 d of age.

In the VA treatment, chickens were provided with VA to the range via a transparent pop-hole cover for the entire duration of the experiment. Therefore, chickens had VA to the range even when the pop holes were closed. Transparent pop-holes were made from clear polycarbonate (3 mm thick) material, that was UV resistant and permitted 85% light transmission (Suntuf, Palram Australia, Victoria, Australia).

Chickens in the EC treatment were provided with a more complex environment than industry standard. Increased EC was achieved by providing 1 visual barrier per pen (92 cm (L) × 5 cm (W) × 60 cm (H) frame covered in 90% UV density black shade cloth), 1 artificial hay bale per pen (white plastic washing tub (60 cm (L) × 36 cm (W) × 40 cm (H)) filled with shredded color paper (pink, blue, green, white, orange) accessible through holes and 1 fan per pen (40 cm circumference, 30 cm above the ground) set on timers (on for 15 min 4 times daily: 05:00, 10:00; 15:00; 19:00) with colored streamers (1 green, 1 pink, and 1 pearl colored cellophane 28 cm (L), 4 mm (W)) that moved, flapped and made a fluttering noise when the fan was turned on. Physical items were based on the scientific literature (vertical panels Bizeray et al. (2002a); Cornetto and Estevez (2001); Ventura et al. (2012); artificial haybales Taylor et al. (2022) and novelty Altan et al. (2013)) in conjunction with chicken meat producer consultation. Specifically, items had to be based on scientific evidence but were also considered practical to implement on farm. For example, the artificial haybale was developed after identifying research that showed improvements to chicken behavior and welfare (Bailie et al., 2013), considered producer concerns regarding the biosecurity risks of providing artificial haybales in commercial conditions (i.e., introducing mycotoxins or salmonella) and had been shown to be safe for meat chickens (Taylor et al., 2022).

Assessing Individual Range Use

Range access was provided to all chickens from 21 d of age, through 1 pop hole (1,300 mm (L), 350 mm (H); 52 mm/bird). Pop holes were open from 06:30 to 19:30 each day from 21 to 31 d of age, but only between 06.30 to 09.30 and 17.30 to 19.30 from 32 to 41 d of age due to behavioral testing (results not included in this manuscript). Access at dusk and dawn was provided in alignment with preferred times of day for ranging (Taylor et al., 2017).

At 17 d of age, silicone leg bands (1.5 mm thick) containing a unique radio frequency identification (**RFID**) tag (ALN 9715 Glint, Alien Technology, CA) were placed on all chicks. The leg bands were designed to stretch as chickens grew (designed by Dr. Tugrul Durali, 1.5 mm silicone from Swift Supplies, Beenleigh, QLD, Australia and cut to design by The Laser Co, West Ryde, NSW, Australia). In each pen, chickens were detected via RFID antennas (1200 (L) × 180 (W) × 20 (H) mm; RL-A1200 12dBi Asset Management UHF RFID Antenna, Reliable RFID, Shenzhen, China) placed at the pophole and 5 m into the range area from the pophole. The range area between the pophole and the RFID antenna at 5m was considered the "close range" and the range area further than 5 m was considered the "far range." At each location 2 antennas were placed side by side to determine directionality of chicken movement, the gap between the 2 antennas was variable (between 2 and 20 cm). The antennas were connected to an RFID reader (Impinj Speedway R420 4 port UHF RFID reader, Impinj, Seattle, WA) which read the tags and output data via a wired serial data connection to a computer running data collection software (Clearstream RFID by Portable Technology Solutions, Calverton, NY). The data collected included the unique tag identification number, time and date stamp, antenna identification and signal strength. At the end of the experiment, the leg bands with RFID tags were removed from all chickens and were passed over an RFID antenna to ensure the tag was functional. Any chickens with a nonfunctional leg band were excluded from all analysis.

RFID Technology Validation

Although the same RFID system had been previously validated for laying hens (Sibanda et al., 2020), we utilized different leg bands and flat antennas (compared to antenna in poly pipe tubing) to accommodate faster growing meat chicken morphology and behavior. Therefore, the reliability of the RFID system was validated, which was achieved through a series of observations of range access via video cameras. All pens were observed across 3 d for three 30-min intervals by 1 trained observer. The number of chickens that moved in and out of the shed were counted and compared to the RFID data. The RFID data showed to be relatively unreliable to detect every range visit; such that between 30 and 40% of all transitions across the antenna (in or out) were missed. Importantly, there were no false readings detected (i.e., determining a chicken crossed the antenna when it did not) and the error was the same across all pens (nonparametric independent-samples, median test $\chi^2_{(13,37)}$10.0, P = 0.691; Kruskal-Wallis $\chi^2_{(13,37)}$11.0, P = 0.607). Subsequent work has improved the reliability of this RFID system (by changing the size and orientation of the RFID chip on the chicken), however for the current study it should be noted that the level of range use is underestimated, although the relative difference between treatment groups is considered reliable.

Climate Variables

Climate data were collected 24 h a day at 5-min intervals from 9 d of age until 42 d of age via a Provantage 2 weather station with UV and Solar radiation sensors (Davis Instruments, Hayward, CA). The average daily climate variables during a portion of rearing (9−13 d of age) and ranging (21−41 d) were calculated. Indoor lux was measured with a handheld Lux meter (Testboy TV 335 Digital LED/Lux Meter, IC-TTV-335, Testboy GmbH, Vechta, Germany) at the center of the pen 1 time during the experiment; on the day that birds arrived (approximately 10:00) but before birds were placed in the pen. Lux was assessed across all pens within 5 min.

Behavioral Sampling

The proportion of chickens in each location of the pen was calculated at hourly intervals between 06:00 and 22:00 on d 3, 7, 8, and 28. Each pen was nominally divided into 5 parts based on resources (i.e., each location was not an equal proportion of the pen; Figure 1).

Behavioral scan samples (Table 1) were taken at the group level each hour between 06:00 and 22:00 twice during wk 1 (d 3 and 7), once during wk 2 (d 8) and once during wk 5 when the pop holes were open (d 28). Behavioral observations were focused on the impact of the rearing treatment on behavior (n = 3) but were not conducted in the final week of rearing (wk 3) as assessments of leg health, cognition, and stress responses were conducted on a subsample of the birds (results not reported in this manuscript) and therefore pen behavior was not analyzed due to the potential of human impact on bird behavior.

Individual body weight of each chicken was measured weekly from day old. Chickens were manually caught

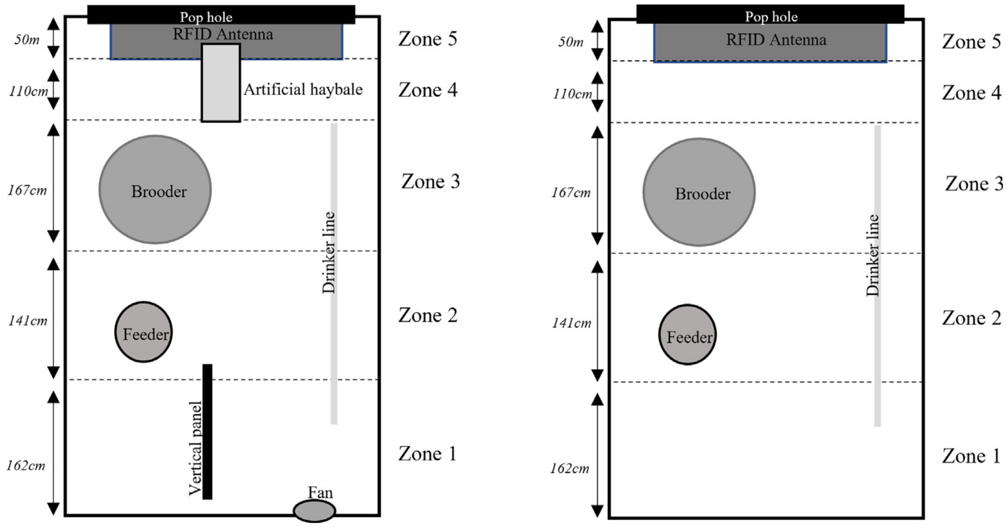

Figure 1. Pen locations outlined for behavioral sampling. The divisions were only theoretical; there were no physical markers in the pens. The areas were the same for all pens, however the diagram on the left shows which enrichment item were associated with each zone for chickens provided with environmental complexity chickens, relative to chickens provided with visual access to the outdoor range and control chickens which is outlined in the diagram on the right.

and placed in a large tub located at the pen door. Chickens were weighed by placing birds in a bucket hung from digital hanging scales (Shinko Denshi, RoHS Compliant, Japan) in an area immediately adjacent to the pen and returned to the pen immediately after weight was recorded. Chickens were sexed postmortem. Due to an error with feed consumption records, we do not report feed conversion ratio data.

Statistical Analysis

Statistical analysis was performed using SPSS software (v26, IBM Corp, Armonk, NY). The difference in sex ratios between treatment groups were analyzed with a chi square analysis. The effect treatment on the proportion of chickens that accessed the range, and far range, were analyzed with a generalized linear mixed model with a binomial distribution (accessed the range or not). Time spent on the range and the number of days that the range was accessed were analyzed with a General linear mixed model. Cox regressions were performed to determine if there was a difference in latency to range across treatments. The number of chickens in each zone was not normally distributed and was therefore analyzed with a binary logistic regression, with number of chickens in zone x as the numerator and total number of chickens per observation as the denominator to account any differences in the number of chickens (present or visible) per pen - the pen was the experimental unit. Body weight was analyzed with a general linear mixed model and included age, treatment and sex and the interactions between age, treatment, and sex. Lux data were analyzed with an ANOVA. In all models, treatment and sex and the interaction between treatment and sex were included as fixed factors and pen nested within treatment as a random factor. Interactions were removed from the model if they were not significant, and removal improved model fit. Multiple comparisons were corrected using the Bonferroni method. Estimated Marginal Means are reports unless otherwise noted.

RESULTS

There was no difference in sex ratio between treatment groups ($\chi^2_{(2,15)}$ 2.50, $P = 0.286$; Table 3).

Table 1. Ethogram for behavioral scan sampling of chickens in the home pen throughout life.

Behavior	Description
Feeding	Pecking at feeder
Drinking	Pecking at nipple drinker
Inactive	Breast in contact with the litter with legs either directly under the body or with 1 leg stretched. Chicken may be pecking at substrate or stationery.
Locomotion	Chicken moves in any direction without performing any other activity listed
Pecking	Pecking walls, antenna, or enrichment items
Foraging	Standing whilst scratching and pecking at wood shaving litter
Comfort	Preening: Beak moved through feathers, may be accompanied by ruffling of feathers
	Dustbathing: Chicken rubs from side to side in substrate with feathers and wings periodically ruffled and shaken
Other	Any other behavior not listed
Not visible	Chicken not visible in the recorded video

Table 2. Climate variables collected from an outdoor weather station during rearing (wk 2−3) and when chickens had access to the outdoor range (wk 4−6).

Climate variable	Wk 2	Wk 3	Wk 4	Wk 5	Wk 6
Temperature (C°)	11.3 ± 0.5	12.4 ± 0.4	11.6 ± 0.5	12.2 ± 0.4	14.9 ± 0.5
Humidity (%)	75.3 ± 0.5	68.7 ± 0.4	80.0 ± 0.2	69.8 ± 0.6	50.2 ± 0.7
Dew point (C°)	6.8 ± 0.6	6.5 ± 0.5	8.2 ± 0.5	6.1 ± 0.4	2.9 ± 0.4
Wet bulb (C°)	8.6 ± 0.6	8.7 ± 0.5	9.6 ± 0.5	8.5 ± 0.5	7.1 ± 0.5
Barometer (hg)	30.4 ± 0.0	30.5 ± 0.0	30.3 ± 0.0	30.8 ± 0.0	30.8 ± 0.0
Wind speed (mph)	3.8 ± 0.1	4.0 ± 0.1	4.7 ± 0.1	5.6 ± 0.1	4.9 ± 0.1
Wind chill (C°)	10.7 ± 0.5	12.1 ± 0.4	10.9 ± 0.5	11.3 ± 0.4	14.5 ± 0.5
Rain rate (mm/h)	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Solar radiation (W/m^2)	147.2 ± 6.2	217.7 ± 6.6	175.6 ± 5.5	206.4 ± 5.5	285.0 ± 9.1
High solar radiation (W/m^2)	157.5 ± 6.6	225.5 ± 6.7	175.7 ± 5.7	223.4 ± 6.7	294.1 ± 9.2
UV index	0.4 ± 0.0	0.6 ± 0.0	0.6 ± 0.0	0.8 ± 0.0	0.9 ± 0.0

Climate Variables

The climate was temperate for summer in Armidale (NSW, Australia), with relatively low temperatures, little rain and lower UV index than expected (Table 2). Lux at the center of the pen was higher in VA (36.0 ± 2.4 lux) than control (27.6 ± 1.9) and EC groups (26.8 ± 1.8; $F_{(2,17)}$5.93, $P = 0.013$).

Pen Behavior

There was an effect of treatment on the number of chickens found in zone 4 (containing the artificial haybale) in wk 1 ($\chi^2_{(2,305)}$ 11.28, $P = 0.004$) and wk 5 ($\chi^2_{(2,305)}$ 11.83, $P = 0.003$) and a trend in wk 2 ($\chi^2_{(2,280)}$ 5.67, $P = 0.059$; Figure 2). Chickens from the EC treatment were observed more frequently in zone 4 than the control ($P = 0.01$) and VA chickens ($P < 0.001$) in wk 1 and the control chickens in wk 2 ($P = 0.055$) and wk 5 ($P = 0.002$; Figure 2).

There was a difference between treatment groups on the number of chickens observed in zone 5 (adjacent to the pop hole) in wk 1 ($\chi^2_{(2,807)}$ 6.76, $P = 0.034$), wk 2 ($\chi^2_{(2,280)}$ 5.99, $P = 0.050$) and wk 5 ($\chi^2_{(2,305)}$ 37.48, $P < 0.0001$; Figure 2). More control chickens sat in zone 5 than VA chickens in wk 1 ($P = 0.030$; Figure 2). Fewer EC chickens were observed in zone 5 than VA chickens in wk 2 ($P = 0.044$) and in wk 5, more VA chickens were found in zone 5 than control ($P < 0.001$) and EC ($P < 0.001$) chickens (Figure 2).

There was no difference between the number of chickens in zone 1 in the first ($P = 0.573$) or fifth ($P = 0.203$) week of life (Figure 2). However, there was an effect of treatment in wk 2 ($\chi^2_{(2,280)}$ 12.52, $P = 0.002$); fewer VA chickens were in zone 1 than control ($P = 0.06$) and EC chickens ($P = 0.009$; Figure 2). There was no difference between treatment groups at any age on the number of chickens in zone 2 (feeder zone) or zone 3 (brooder zone) (all $P > 0.05$; Figure 2).

In wk 1, chickens from the VA treatment were more active ($\chi^2_{(2,802)}$ 12.52, $P = 0.002$) than chickens from both the control ($P = 0.007$) and EC treatment ($P = 0.006$) and spent more time foraging than control chickens ($\chi^2_{(2,280)}$ 6.64, $P = 0.036$), but not EC chickens (Figure 3). Additionally, in wk 1, chickens from the EC treatment pecked more frequently ($\chi^2_{(2,802)}$ 11.67, $P = 0.003$) than chickens from the control ($P = 0.019$) and VA treatment ($P = 0.005$; Figure 3). Additional observations of tactile interactions with pen resources and enrichment items in the EC pens over time are provided in supplementary data.

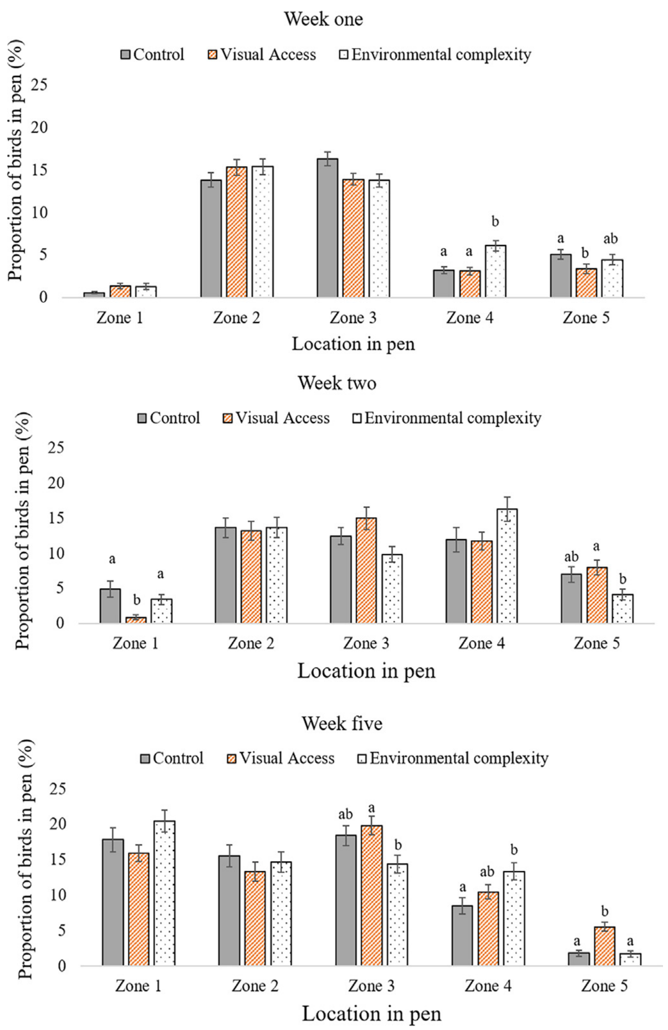

Figure 2. Proportion of chickens within a pen that were found in zone 1 (back of pen near entry door), zone 2 (containing the feeder), zone 3 (containing the brooder), zone 4 (containing a haybale for chickens provided with environmental complexity (EC chickens) but nothing for control and chickens provided with Visual Access to the outdoor range during rearing (VA chickens)) and zone 5 (adjacent to the pop hole, which was solid for EC and control chickens but transparent for VA chickens) during wk 1 (top) wk 2 (middle) and after range access was provided in wk 5 (bottom).

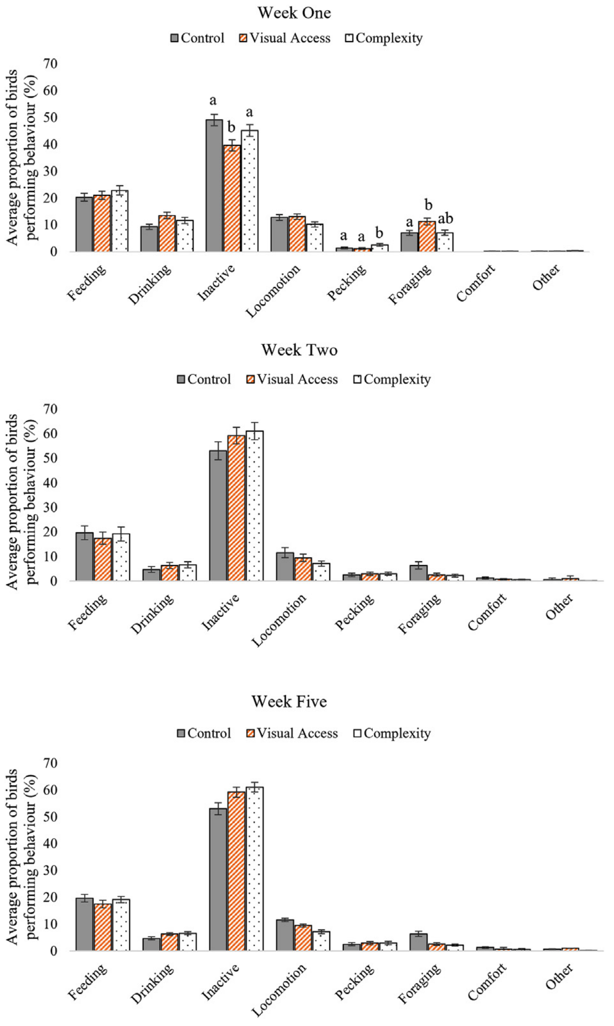

Figure 3. Behavioral time budgets for chickens in control environments (grey solid bar), with visual access to an outdoor range (orange striped bar) or with environmental complexity (white bars with black dots) during wk 1 (top graph), wk 2 (middle graph) and wk 5 when the range doors were open (bottom graph). Data are presented as the average proportion of chickens in a pen performing each behavior at 1 scan sampling interval (i.e., each hour between 6:00 and 22:00). Differing subscript indicates a difference between treatment groups for a particular behavior ($P < 0.05$).

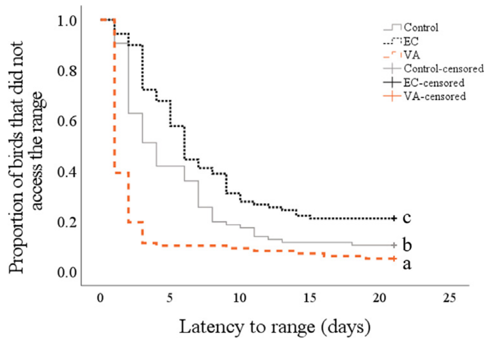

Figure 4. Survival curve indicating the proportion of chickens that did not access the outdoor range and the latency for chickens to access the range (days) for chickens raised in a standard environment (control, solid grey line), with visual access to the range (VA, orange dash lined) or environmental complexity (EC, black dotted line). Differing subscript indicates a difference in the proportion of chickens that accessed the range and the latency to range ($P < 0.05$).

Ranging Behavior

The majority of chickens accessed the range at least once (87.9% of all chickens accessed the range over the course of the experiment) and there was a trend for treatment to differ in the number of chickens that accessed the range within a pen ($\chi^2_{(2,15)}$ 4.98, $P = 0.083$; Table 3), such that more VA chickens accessed the range than EC chickens ($P = 0.015$). The proportion of chickens that accessed the range further than 5 m from the shed was very low (5.9% of all chickens). There were too few chickens that accessed the far range to confidently analyze differences between treatments.

More chickens from the VA treatment accessed the range and were faster to do so when first given the opportunity than chickens in the control and EC treatment ($\chi^2_{(2,273)}$ 64.9, $P < 0.001$; Figure 4).

Chickens from the VA treatment access the range on more days ($F_{(2,188)}$5.98, $P = 0.003$; Figure 5). compared to control ($P = 0.023$) and EC chickens ($P = 0.002$). VA chickens spent longer on the range ($F_{(2,188)}$4.01, $P = 0.020$) than chickens in the control ($P = 0.020$) and EC ($P = 0.012$) group (Figure 5).

Mortality

There was an effect of week ($F_{(5,39)}$ 4.02, $P = 0.005$) and of treatment ($F_{(5,72)}$ 5.53, $P = 0.006$) on mortality. There were fewer deaths in the VA treatment group compared to the control ($P = 0.002$) and EC ($P = 0.024$) groups (Figure 6). There were more deaths in the first week of life compared to wk 2 ($P < 0.001$), wk 3 ($P = 0.002$), wk 4 ($P < 0.001$), wk 5 ($P < 0.001$) and wk 6 ($P < 0.001$). There was no difference in mortality between any of the other weeks. There was no interaction between week and treatment on mortality ($P = 0.637$).

Table 3. Proportion of females and males in each treatment group and the proportion of chickens that access the outdoor range and the area furthest from the shed (>5 m) at least once during the experiment.

	Control	Visual access	Environmental complexity
Proportion of female chickens	44.1 ± 7.4	49.3 ± 5.9	49.1 ± 3.3
Proportion of male chickens	55.9 ± 7.4	50.7 ± 5.9	50.9 ± 3.3
Proportion of chickens that accessed the range	88.0 ± 3.8^{ab}	94.8 ± 1.9^{a}	78.7 ± 3.5^{b}
Proportion of chickens that accessed the far range	1.17 ± 1.2	1.17 ± 1.2	0.0 ± 0.0

Differing subscript indicates a difference between treatment groups ($P < 0.05$).

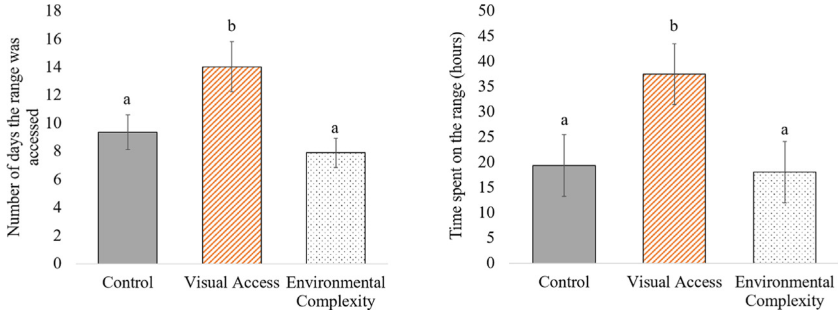

Figure 5. The avereage number of days (left) and hours (right) an individual spent on the range throughout the experiment (maximum of 21 d). Differing subscript indicates a difference between treatment groups ($P < 0.05$).

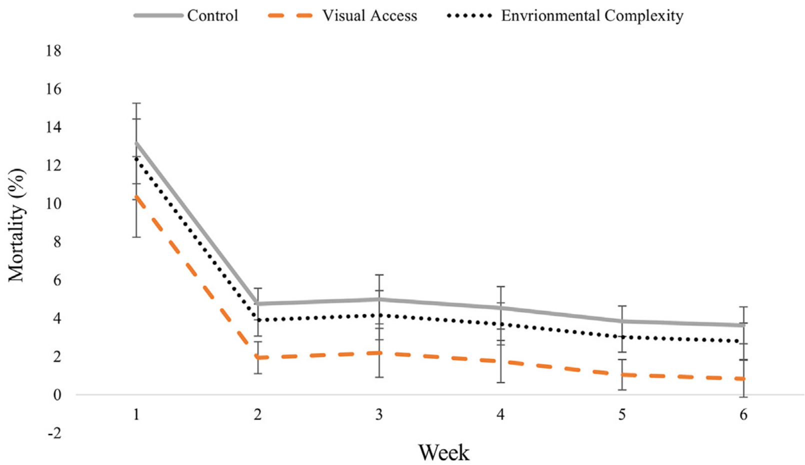

Figure 6. Weekly mortality for chickens reared in a control environment (solid grey line), with visual access to an outdoor range (orange dashed line) or environmental complexity (black dotted line).

Body Weight

There was no interaction between treatment, sex and age ($P = 0.627$) but there was an interaction between treatment and sex ($F_{(2,1285)}29.2$, $P = 0.054$) therefore females and males were analyzed separately. There was no interaction between age and treatment for either female (0.611) or male ($P = 0.969$) body weight. There was a main effect of treatment on female body weight ($F_{(2,634)}7.8$, $P < 0.001$) but not male body weight ($P = 0.789$). Female chickens from the VA treatment group had lower body weight than control and EC chickens before range access at 21 d of age ($F_{(2,12)}6.47$, $P = 0.013$) and lower body weight than EC chickens after range access at 42 d of age ($F_{(2,16)}4.03$, $P = 0.038$; Table 4).

DISCUSSION

VA to the outdoor range from day old improved the latency to range, time spent on the range and the number of days chickens accessed the range. Environmental

Table 4. Body weight (g) of female and male chickens from day old to 42 d of age.

Age (d)	Sex	Control	VA	EC	*P*-value
0	F	47.5 ± 0.8	46.0 ± 0.7	46.5 ± 0.7	0.406
	M	47.6 ± 0.7	46.5 ± 0.8	46.0 ± 0.7	0.368
7	F	178.7 ± 3.6	165.3 ± 3.2	176.2 ± 3.3	0.061
	M	183.9 ± 4.2	176.4 ± 4.4	181.5 ± 4.4	0.604
14	F	520.6 ± 9.6	480.4 ± 8.5	493.0 ± 9.1	0.223
	M	529.7 ± 12.3	510.9 ± 13.2	512.7 ± 13.0	0.629
21	F	**1000.4 ± 20.2**[a]	**919.9 ± 17.9**[b]	**987.3 ± 19.5**[a]	**0.013**
	M	1032.6 ± 25.9	1015.7 ± 28.2	1059.0 ± 28.1	0.474
28	F	1649.6 ± 25.9	1580.1 ± 22.9	1645.9 ± 24.4	0.066
	M	1753.01 ± 37.3	1744.0 ± 39.8	1769.2 ± 39.3	0.839
35	F	2336.6 ± 49.1	2269.7 ± 43.5	2392.9 ± 46.3	0.063
	M	2565.9 ± 58.2	2574.9 ± 63.5	2643.8 ± 64.3	0.629
42	F	**2958.3 ± 85.8**[a]	**2806.6 ± 75.7**[b]	**3017.4 ± 83.8**[a]	**0.038**
	M	3144.8 ± 86.0	3304.2 ± 91.9	3271.8 ± 90.8	0.237

Note: Bold lines indicate that bold highlights time points where there was an effect of treatment on body weight. Chickens were reared in standard rearing environments (Control), with visual access to the outdoor range (VA) or with additional environmental complexity (EC).
[ab]Differing subscript indicates significant differences between treatments within sex at an age.

complexity provided indoor, via an artificial haybale, fan with streamers and a visual barrier, did not increase range use – in fact, such environmental enrichment may reduce ranging behavior of meat chickens. Therefore, VA is an effective method to improve ranging.

According to our hypothesis, providing VA to an outdoor range increased chicken activity inside the shed and subsequently improved ranging behavior. This finding is in alignment with Blatchford et al. (2009) who showed that the activity of meat chickens increased when they were reared with 200 lux lighting (compared to 5 lux and 50 lux). However, VA chickens were only more active than control and EC chickens in the first week of life. Although activity of VA chickens was not greater at the age when birds were provided with the opportunity to range, the early life experience of increased activity may have improved leg health and consequently improved ranging. Indeed, the frequently of range visits has been associated with good leg health in meat chickens (Taylor et al., 2018). However, it is also plausible that an alternative mechanism may have been impacted by VA to the range which subsequently increased ranging behavior. Further investigation is required to understand the mechanism.

The impact of the pop hole transparent windows could be due to numerous factors associated with increased VA; increased light intensity, UV light exposure, complexity and variation in the environment, or familiarity and each such factor may have various effects on chicken behavior and welfare. For example, UVA wavelengths have been shown to facilitate social interactions (i.e., signaling, and foraging decisions), improve leg health (improved gait scores) and reduce fearfulness (James et al., 2018). Although chickens cannot see UVB, light at this wavelength can improve vitamin D synthesis, which could have an impact on leg health and subsequently activity, which is particularly important in faster growing chickens such as those in the current study and optimal leg health appears to be an important factor relating to use of the outdoor range (Taylor et al., 2018; Taylor et al., 2020). However, the Perspex material used in the current study was UV resistant. As such, the effects on chicken behavior are unlikely associated with an increase in UVA or UVB light. The material did however transmit 92% of light and therefore the increased light intensity experienced by the chickens may be the most probable cause for the observed behavioral changes. Whilst it seems highly plausible that increased light intensity is responsible for higher activity and may have resulted in more range use by the chickens, other components of light such as dusk and dawn periods, could also play a role and should be further investigated.

Alternatively, having had VA to the range for 3 wk prior to the ability to access it could have made VA chickens more familiar with the outdoor range. Habitation to the outdoor range area could have been the reason that more chickens accessed the range and were quicker to do so. Indeed, Jones et al. (2002) provided evidence that chicks were more likely to enter a novel environment if a familiar stimulus (an odorant) was present and meat chickens provided with twice daily visual contact with were more likely to approach the human stimulus later in life (Taylor et al., 2022). There were fewer VA chickens found in the zone close to the pop hole in wk 1 compared to control chickens, although there were very few chickens observed in this area (it was a smaller area than other zones) the numerical difference was very small this may indicate that young chicks were avoiding the Perspex and found a component of it aversive (i.e., possible temperature differences due to different material). Nevertheless, this behavior was not observed in wk 2 which may indicate it was the novelty in the environment that may have been aversive, and the birds habituated to it in wk 2. When the pop holes were open (3 wk onwards), there were more VA chickens found in the zone close to the pop hole compared to control and EC chickens, this was likely a reflection of more range use – and therefore more birds in the transition area between indoor and outdoor environments. Better understanding the environments (i.e., climatic differences) and aversion or attraction to the transparent pop holes may help to understand the impact of providing VA to the outdoor range on the chickens.

Providing a complex indoor environment with various dynamic enrichment items did not improve range use, and in fact it reduced use of the outdoor range area. This may reflect that an indoor complex environment is preferred. The environmental enrichments chosen in this study aimed to alter use of space, leg health and reduce fear in meat chickens, as these characteristics have been shown to be related to range area by meat chickens (Taylor et al., 2018; Taylor et al., 2020). Vertical barriers have been shown to effect utilisation of the available space and can have an impact on chicken temperament. For example, Bizeray et al. (2002b) and Ventura et al. (2012) showed that vertical barriers result in a more uniform distribution of chickens throughout a home pen, improve leg health and reduce fearfulness.

Hay bales are well utilized (Bergmann et al., 2017) and have been shown to lead to improvements in leg health, evident by improvements to gait scores (Bailie et al., 2013; Baxter et al., 2018; Tahamtani et al., 2020) and shorter latency to lie (Bailie et al., 2013). However, our discussions with industry persons suggest that there is biosecurity concerns (for example, mycoplasma and salmonella) that can prevent the inclusion of organic-based items on farm. Therefore, we manufactured an artifical haybale, to mimic what we perceived to be important characteristics of a haybale for meat chickens; something to sit next to when chickens were young—which may provide a feeling of safety—and provides opportunities for chickens to peck and manipulate the resource and acts as a type of perch/platform for chickens to rest on (Bergmann et al., 2017). Of note, we did not see chickens sitting on top of the artifical haybale, which may suggest that the height and or material was not optimal for the chickens. EC chickens used zone 4 more frequently than control and VA groups, even in wk 1 when we expected to find most chickens under the brooder lamp. The artificial haybale was in this zone, suggesting that this was an important stimulus in the rearing environment. Previous research shows that haybales—when placed in the outdoor range area—are effective at encouraging laying hens out on the range (Nagle and Glatz, 2012). It may be that we inadvertently caused the opposite response by providing an artificial haybale *inside* the shed, compared to providing haybales in the outdoor range.

We also provided EC chickens with fans with streamers that were activated 4 times each day to provide some novelty in the environment. Anderson et al. (2021b) and Anderson et al. (2021a) showed that novelty (i.e., items that were changed every 3 d) reduced anxitety and increased positive mood. There was no evidence that EC chickens found the fan with streamers aversive, as they were observed in the pen zone that contained the fan (zone 1) as much (or more than VA chickens in wk 2) as control and VA chickens. Although, the stimuli were provided based on the available literature and industry discussions, the provision of a vertical barrier, an artifical haybale, and novelty in the rearing envrionment did not improve range use.

Few chickens in all treatment groups were found in zone 1, which was expected as few other essential resources, such as heat, water, and food, were contained in other areas. Interestingly, the number of chickens found in the back half of the pen (zone 1) increased approximately 15% between wk 1 and 2 and wk 5 in all treatment groups. This may be an age-related effect with chickens distributing themselves more evenly throughout the pen with age. However, this finding in conjunction with few chickens in zone 5 (adjacent to the open pop hole) in wk 5, could suggest that chickens inside the shed may find the open pop hole aversive, perhaps related to differences in climate, or fear of the range area, or simply to avoid chicken traffic coming in and out of the pop hole. This is an interesting scientific finding and perspective, as much of the research on free-range meat chickens focus on the impact of the range area on ranging chickens, rather than the impacts of open pop holes on chickens that choose to stay indoors.

This research was conducted in relatively small pens and small group size. How this translates to a commercial farm is unknown. It is important to validate these results on commercial farms and understand more about the underlying mechanisms before recommendations can be made for on farm use. For instance, understanding the mechanism at play will help producers provide the appropriate resources in the shed, that is, to test whether windows on the roof or higher in the shed may lead to the same effect as providing transparent pop holes at chick height.

CONCLUSIONS

Our findings suggest that providing VA to the range in early life improved ranging behavior, reduced mortality and may have negatively impacted growth rate. Environmental enrichment items located in the indoor environment were used and appeared to conflict motivations to access an outdoor range.

ACKNOWLEDGMENTS

The authors acknowledge the financial contribution from AgriFutures (PRJ-011546). The authors with to acknowledge Natalie Mendes, Manisha Kolakshyapati, Terence Sibanda, The Centre for Animal Research and Teaching (CART) at UNE in particular Timothy Elliot and Justin Bailey, for their assistance in data collection and monitoring the animals. The authors thank the UNE Science Engineering Workshop and UNE Estate and Built Environment for their assistance with shed modifications including constructing the transparent pop holes. The authors also wish to acknowledge the contribution of Tugrul Durali for sharing his RFID leg band design to accommodate the growth of the chickens.

DISCLOSURES

Peta S Taylor reports financial support and article publishing charges were provided by AgriFutures (PRJ-011546).

SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.psj.2023.103079.

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