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Fast-growing broiler chickens range more in a silvopasture than a grass pasture based on live observations

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Broiler chickens with free-range access often show low use of the outdoor space and providing access to a silvopasture (intentional integration of vegetation and animal production) may increase range use. The study aim was to evaluate the effect of pasture system (silvopasture; open grass pasture) on range use in fast-growing broiler chickens. Fifty-three or 54 birds per experimental unit in two experiments were provided access to 125m^2 silvopasture plots ($\bar{x}$ 32% canopy cover) or open grass pasture plots (no canopy cover) from day 24 of age. Plot-level range use (% of the flock outside) was assessed from photographs for 16 days in Experiment 1 and 18 days in Experiment 2. In Experiment 2, live observations of range use were performed on days 29, 30, 34, 35, 40, and 41. We used generalized linear mixed models to predict broiler ranging activity at different times of day (morning, midday, afternoon) as a function of average daily temperature, bird age, and pasture treatment. Younger birds were more likely to range on cold days, while older birds ranged more on warm days, consistent across live observations and photographs. Live observations showed more birds in silvopastures than open pastures, whereas photographs indicated the opposite. Bird counts may be underestimated in the photos, due to visual obstruction by vegetation, especially in the silvopastures. The contrasting outcomes highlight that the choice of sampling method strongly influences conclusions about range use. Consistent across photographs and live observations, range use followed a diurnal rhythm, with highest use in mornings and afternoons. Overall, silvopasture provided age- and temperature-dependent benefits for broiler chickens, highlighting the importance of giving birds the choice to range outdoors or remain indoors.

KEYWORDS

agroforestry, animal welfare, broiler, free-range, silvopasture

1 Introduction

Chicken production systems with outdoor access provide more space and more environmental complexity than indoor-only production systems. This allows birds to express natural behaviors such as foraging, scratching, sunbathing, and dustbathing (Knierim, 2006; De Jonge and Van Trijp, 2013; Vanhonacker et al., 2016; Fanatico et al., 2016). Time spent outdoors is also correlated with positive welfare outcomes, including reduced anxiety and improved gait compared to indoor counterparts (Grigor et al., 1995; Stadig et al., 2017a; Taylor et al., 2018).

Most chickens with free-range access, however, do not go outside (Bubier and Bradshaw, 1998; Zeltner and Hirt, 2003; Dawkins et al., 2003; Hegelund et al., 2005; Fanatico et al., 2016). Moreover, amongst the small percentage of birds that do venture outside, most tend to stay close to the indoor facility (Hegelund et al., 2005; Fanatico et al., 2016; Stadig et al., 2017a). The benefits of outdoor production systems are limited when the range is underutilized; when birds in the range mostly stay close to the housing facility, vegetation will be trampled (Bubier and Bradshaw, 1998) and excreta can result in excessive nutrient deposition (point-contamination; (Permin et al., 1999; Van De Weerd et al., 2009; Singh and Cowieson, 2013). As a result, the animal welfare benefits of outdoor access do not always manifest in birds with access to free ranges (Stadig et al., 2017b; Taylor et al., 2018). Thus, to better design free-range production systems and improve chicken welfare at free-range facilities, there is a need to better understand the factors that determine chicken behavior and range use.

Range use and ranging distance has been linked to birds' daily activity cycles (Collias and Collias, 1967; Bubier and Bradshaw, 1998; Dawkins et al., 2003; Jones et al., 2007; Stadig et al., 2017a), fear (Grigor et al., 1995; Stadig et al., 2017a), leg health (Taylor et al., 2018), and genetic strain (Nielson et al., 2003). Ranging behavior follows a diurnal rhythm, with most birds recorded outside after sunrise and before sunset (Collias and Collias, 1967; Dawkins et al., 2003). Genetic strain can also impact range use, with a greater proportion of slow-growing broilers recorded outside compared to fast-growing broilers between 6–12 weeks of age (Nielsen et al., 2010). Range use has also shown to be influenced by environmental conditions (Dawkins et al., 2003; Hegelund et al., 2005; Stadig et al., 2017b). Increasing wind speed and precipitation resulted in fewer laying hens on the range (Hegelund et al., 2005). The same researchers reported a parabolic relationship between temperature and range use, with the number of hens increasing until 17°C and decreasing thereafter (Hegelund et al., 2005). Rain, high levels of solar radiation, and high wind speeds were associated with reduced range use among slow-growing broilers, while temperature was positively associated with the number of broilers outside (Stadig et al., 2017a).

Understanding the environmental predictors of range use offers an opportunity to manipulate the range pasture to encourage greater use of outdoor ranges. Converting open pastures to silvopasture for example, has the potential to mitigate the environmental conditions that keep chickens indoors. Silvopasture systems involve integrating tree, forage, and livestock production in a single plot of land. Chickens prefer natural vegetation in their range (Collias and Collias, 1967; Dawkins et al., 2003; Dal Bosco et al., 2014; Stadig et al., 2017a), and a silvopasture system can provide this vegetation, offering a more complex and varied habitat. The presence of trees has been shown to be positively correlated with both the time spent outside and the amount of range utilized in broiler chickens (Dawkins et al., 2003; Jones et al., 2007). Moreover, silvopasture has been linked to increased productivity and improved welfare. Broilers with access to pastures with mature hedgerows gained more weight without increasing feed costs compared to those in open pastures (Delgadillo et al., 2021), and access to silvopastures improved leg health in fast-growing broilers (Paneru et al., 2023). Furthermore, mortality due to predation was lower in flocks with access to olive trees or sorghum in the range than in those kept in open grass pastures (Dal Bosco et al., 2014).

Previous research has examined the influence of artificial shelters and vegetation on range use in laying hens (Hegelund et al., 2005) and slow-growing broilers (Jones et al., 2007; Dal Bosco et al., 2014; Stadig et al., 2017a; Stadig et al., 2017b). Yet, the impact of vegetation on fast-growing broilers ranging behavior is understudied. It remains unclear whether access to silvopasture benefits range use in fast-growing broilers, which are the most common type of broiler chicken used in the United States. The objective of our study was to evaluate the effect of silvopasture versus open pasture access on range use in fast-growing broilers, and how age, temperature, and time of day impact this range use. We hypothesized that a silvopasture system would result in more broilers ranging outside compared to broilers in an open grass pasture system. We theorized that the canopy in silvopastures would provide protection from weather extremes, resulting in more birds in the silvopasture on hot and cold days compared to grass pasture. We expected to see a diurnal ranging pattern with most ranging activity in mornings and evenings. We also hypothesized that broilers would use the range more as they aged and became familiar with their environment.

2 Materials and methods

Two experiments were conducted in April-May 2021 in June-August 2021. All procedures were approved by the Virginia Tech Institutional Animal Care and Use Committee (IACUC protocol 20-044). Mixed-sex Ross 708 fast-growing broilers were used in both experiments, with 886 birds in Experiment 1 and 648 in Experiment 2. The distribution of sexes among pens or plots was not standardized. Chicks were Marek's vaccinated at the hatchery (Harrisonburg, Virginia, USA) and transported to the research facility. Following arrival, chicks were randomly assigned in groups of 73 or 74 individuals in Experiment 1, and groups of 53 or 54 individuals in Experiment 2, and subsequently housed in 12 indoor pens. Pens (5.7 m^2) contained new pine wood shavings at approximately 5 cm depth, a feeder (Superbowl poultry feeder, LaGrange, NC, USA), two drinkers (Plasson® Broiler Drinker complete, Or-Akiva, Israel; Stout Stuff LLC, Bentonville, AK, USA), a heat lamp (day 1-8), and a cardboard feed flat with feed (day 1-8). The chicks received water and feed *adlibitum*, with commercial diets (starter: week 0-2; grower: week 3-4; and finisher: week 4-6) meeting species recommendations (National Chicken Council, 2017). Birds were kept at ambient temperatures of 35°C on day 1 and the temperature was gradually reduced to 23°C in week 3. Lighting was provided 24 h for the first week and reduced to 12 h light and 12 h dark until week 3.

Birds were transported to the pasture-based plots on day 22 (Experiment 1) or 23 (Experiment 2). In Experiment 1, 4 or 5 randomly selected birds from all 12 indoor pens were grouped in crates and assigned to an experimental unit, resulting in 53 birds per unit (8 replicates/treatment). In Experiment 2, all birds from a single indoor pen (53–54 birds) were randomly distributed to an experimental unit (6 replicates/treatment). To acclimatize to the new pasture environment, birds were kept inside their coops for 2 days in Experiment 1 and 1 day in Experiment 2. Pastures were accessible from day 24 until day 42 (Experiment 1) and day 43 (Experiment 2), with the doors continuously open between approximately 8 AM and 5 PM.

Pasture plots (experimental units) were 125 m^2 each (16 in Experiment 1 and 12 in Experiment 2) and were enclosed with 1 m-high electric fences (PoultryNet®, Washington, IA, USA). The chicken coops were constructed with wood, chicken wire and tarp (Skelton et al., 2012), were 6.55 m^2 and contained a feeder, bell drinker, and a wooded platform perch (0.05 m × 0.1 m × 2.4 m). Chicken coops were moved laterally twice within the experimental plot. Mean coop stocking densities were 20.82 kg/m^2 on day 42 in Experiment 1 and 21.80 kg/m^2 on day 43 in Experiment 2.

2.1 Treatments

The silvopasture plots were situated at two sites within close proximity to each other (37°56’05.4”N 79°12’41.8”W and 37° 56’03.6”N 79°12’40.9”W). Each site had 4 replicate plots in Experiment 1 and 3 replicate plots in Experiment 2. The tree species, forage species, and herbaceous ground vegetation in the silvopasture treatment were reported in (Paneru et al., 2023). The canopy coverage was estimated from images (see (Paneru et al., 2023) for methodology), with a mean (± standard deviation) canopy cover of 31.7 ± 16.7% in Experiment 1 and 33.3 ± 10.9% in Experiment 2. The silvopasture consisted of residual mixed hardwoods (primarily hickory, walnut, black cherry & oak) from a thinning conducted in 2014. Canopy trees in the silvopasture are native and common to the mid-Atlantic region and had a diameter (at ~1 meter above the ground) ranging from ~20–40 centimeters.

The open grass pasture plots were situated at two sites in close proximity to each other (37°56’05.8”N 79°12’39.5”W and 37° 56’00.0”N 79°12’41.4”W). Each site had 4 replicate plots in Experiment 1 and 3 replicate plots in Experiment 2. Forage species and herbaceous ground vegetation were reported in (Paneru et al., 2023). Open pastures had no canopy coverage.

2.2 Measurements

2.2.1 Environmental monitoring

We collected temperature data using temperature and humidity loggers (AcuRite Pro Humidity Meter & Thermometer, model 01139, Chaney Instrument Co., Lake Geneva, WI, USA). Loggers were placed within three coops per treatment (six loggers total) and current, minimum, and maximum values were recorded twice daily from day 23 of age (first full day birds were housed in the coops) until day 42 of age (the day birds were loaded for processing). One weather station (WatchDog 1000 Series Micro Station, Spectrum Technologies, Inc., Aurora, IL, USA) per treatment was placed in one of each experimental treatment pasture to record current temperature data at 5-min intervals starting at day 27 of age until day 42 of age in Experiment 1 but not Experiment 2. Additionally, daily average temperatures were retrieved from a local weather station for data collected before loggers were installed.

2.2.2 Range use from photographs

Plot-level range use was assessed hourly from photos for 5 plots per treatment in both Experiment 1 and Experiment 2 using wildlife cameras (HC400 trail camera, Victure, Guangdong, China). Cameras were mounted on poles at approximately 2-m height and placed at approximately 9 m from the plot. The photos were taken between 8:00 AM and 5:59 PM from days 26-41, resulting in a sample of 672 (open pasture in Exp 1), 711 (silvopasture in Exp 1), 800 (open pasture in Exp 2), and 807 (silvopasture in Exp 2) usable photos per treatment. Ranging distance was categorized as near the coop, middle of the range, and far from the coop (Figure 1) using stake flags at each threshold to be able to determine the distance. The total proportion (%) of the flock in the range and the proportion of the flock at each distance were calculated. The number of birds were counted using ImageJ software (1.5.3k, National Institutes of Health, Bethesda, MD, USA). The ‘multi-point’ tool was used for counts by ranging distance (close, middle, far; Figure 1). Observations were categorized by time of day, including morning (8 AM - 12 PM), midday (12 PM – 3 PM) and afternoon (3 PM - 5 PM).

In Experiment 1, vegetation could conceal birds that were ranging in the plot. Therefore, we were only able to determine the minimal count of birds in the range. In Experiment 2, ground vegetation in both treatments was mowed prior to bird placement.

2.2.3 Range use from live observations

In Experiment 2, hourly live observations were performed at plot-level for all plots (6 per treatment) to count the number of birds in the range between 8 AM and 5 PM on days 29, 30, 34, 35, 40, and 41 of age. The observer sat down at 5-m distance from the plot to prevent impacting the birds’ behavior. The proportion (%) of the flock in the range, and at each distance were calculated. Observations were categorized by time of day, including morning, midday, and afternoon.

TABLE 1 Mean number (n) of birds observed outside by distance category (near, middle, or far from the coop), by bird age (in weeks, with no live observations in week 3), and by time of day in silvopasture and open pasture treatments.

Factor	Level	Silvopasture		Open pasture	
		Photo	Live	Photo	Live
Distance	Near	2.1 (0-33)	7.3 (0-42)	2.8 (0-31)	4.7 (0-39)
	Middle	0.2 (0-17)	0.3 (0-11)	0.2 (0-17)	0.1 (0-5)
	Far	0.1 (0-11)	0.1 (0-8)	0.1 (0-18)	0.1 (0-19)
Bird age	3	1.6 (0-8)	–	1.0 (0-6)	–
	4	2.7 (0-21)	5.1 (0-35)	3.9 (0-38)	2.4 (0-23)
	5	5.6 (0-37)	10.2 (0-48)	5.9 (0-32)	5.2 (0-38)
	6	5.5 (0-41)	8.0 (0-47)	6.4 (0-48)	6.9 (0-48)
Time of day	Morning	3.9 (0-41)	15.5 (0-48)	5.0 (0-48)	11.5 (0-48)
	Midday	1.0 (0-13)	1.2 (0-23)	1.9 (0-38)	0.2 (0-4)
	Afternoon	1.8 (0-37)	4.0 (0-36)	1.7 (0-20)	0.7 (0-27)

Numbers in parentheses represent the range of observed values observed in each distance-treatment combination.

birds venturing long distances (Table 1), distance was omitted from all analyses. The mean number of birds observed outside for any one live observation was 6/53 (11.3%), but this varied by treatment, bird age, and time of day (Table 1).

3.3 Morning range use: photographs

The top model to predict photographed range use in the morning included age, temperature, treatment, and the interactions between treatment and temperature and age and temperature (Table 2; Figure 4). Birds were less likely to be observed outside in silvopasture than open pasture (beta = -0.76, 95% CI [-1.01, -0.52], p< 0.001). However, there was an interaction between treatment and temperature (beta = 0.02, 95% CI [0.01, 0.04], p< 0.001), where differences in range use between treatments were greatest at low temperatures and became negligible at high temperatures (Figure 4). When evaluated at the model's intercept (0°C), older birds were less likely to be outside (beta = -0.33, 95% CI [-0.51, -0.15], p< 0.001). However, there was an interaction between age and temperature (beta = 0.04, 95% CI [0.03, 0.05], p< 0.001), where young birds were less likely to be outside on warm days (beta = -0.17, 95% CI [-0.22, -0.13], p< 0.001) and old birds were more likely to be outside on warm days.

TABLE 2 Comparison of regression models describing the proportion of birds photographed outside in the morning as a function of bird age, temperature, and treatment.

Model	*AIC*	*ΔAIC*	w_i
~ *Age × Temperature + Treatment × Temperature*	7146.5	0.0	1.0
~ *Age × Temperature + Treatment × Age*	7155.7	9.2	0.0
~ *Age × Temperature*	7246.9	100.4	0.0
~ *Age × Treatment*	7451.8	305.3	0.0
~ *Age*	7510.6	364.1	0.0
~ 1	7897.0	750.5	0.0

All models included plot as a random effect. Models were compared using AIC and AIC weights (w_i). Only the top 5 models and the null model for reference are presented.

3.4 Midday range use: photographs

The top model to predict photographed activity at midday included age, temperature, and treatment (Table 3; Figure 5). Specifically, birds were less likely to be observed outside in silvopasture than open pasture (beta = -0.57, 95% CI [-0.69, -0.45], p< 0.001) and less likely to be outside on warm days (beta = -0.05, 95% CI [-0.06, -0.03], p< 0.001). Further, older birds were less likely to be outside during midday (beta = -0.33, 95% CI [-0.51, -0.15], p< 0.001).

3.5 Afternoon range use: photographs

The top model to predict photographed activity in the afternoon included age, temperature, treatment, and the interactions between age and temperature and treatment and temperature (Table 4; Figure 6). Overall, birds were less likely to be observed outside in silvopasture than open pasture (beta = -1.33, 95% CI [-1.72, -0.94], p< 0.001). However, treatment and temperature interacted (beta = 0.06, 95% CI [0.04, 0.08], p< 0.001), where birds in silvopasture treatments were more likely to be observed outside at high temperatures (Figure 6). When evaluated at the model's intercept (0°C), older birds were less likely to be outside (beta = -0.80, 95% CI [-1.09, -0.52], p< 0.001). However, we found evidence for an interaction between age and temperature (beta = 0.04, 95% CI [0.03, 0.06], p< 0.001), where young birds were less likely to be outside on warm days (beta = -0.23, 95% CI [-0.31, -0.16], p< 0.001), and old birds were more likely to be outside on warm days (Figure 6).

difference between treatments occurred at 4 weeks of age, when more birds were observed in silvopasture than in open pasture. This difference decreased with age and was reversed by 6 weeks of age. These results suggest that younger birds may be particularly motivated to use areas with partial cover, which also moderates weather extremes, and provides a safer environment when birds are young and more vulnerable to predation. The former was supported by results in the current study, and the latter is supported by the lack of predation loss in slow-growing broilers in ranges with trees or tall grass (Dal Bosco et al., 2014). Predator avoidance becomes a less determining factor as birds age; instead, temperature becomes the primary driver of ranging activity.

We only incorporated live observations in the second experiment. In contrast to the data collected from photographs, our live observations provide support for benefits of a silvopasture on broiler chicken range use. These differences are in part due to the difference in the improved ability for an observer to see a bird during live observations, being able to look around a tree, a tuft of grass, or the coop, which is not possible in still photos. While the counts differ between methods, and the effect of treatment was opposite, the interactive impacts of temperature and bird age remain, reinforcing their impact on range use. In both, older birds were more likely to range on warmer days. This implies that age-dependent thermal comfort is an important determinant for a bird to range outside.

4.4 Midday range use from photographs and live observations

At midday, range use was limited across both treatments and treatment effects were opposite depending on the method of data collection. Fewer birds were photographed in the silvopasture compared to the open pasture. In the live observations, more birds were observed in the silvopasture compared to the open pasture. Neither difference holds much biological relevance, since the mean difference was 1 bird per flock of 53 or 54. An important consideration is the diurnal behavioral rhythm of chickens. Slow-growing free-ranging chickens spent less time actively foraging outside at midday compared to morning or late afternoon in a South African study (Mutibvu et al., 2018). Similarly, the fewest number of slow-growing broilers were observed out in the range around midday (Alvino et al., 2009; Fanatico et al., 2016). Aligning with previous studies reporting peaks of activity in the morning and evening (Dawkins et al., 2003; Nielsen et al., 2010; Taylor et al., 2017), ranging behavior follows a distinct diurnal pattern with low range use around midday regardless of treatment.

4.5 Afternoon range use from photographs and live observations

Aligned with mornings and midday, birds in photos were less likely observed in the silvopasture than in the open grass pasture in the afternoon, while more birds were recorded outside in the silvopasture than in the open grass pasture during live observations. The relationships between temperatures and bird age were the same as for the morning range use, with young birds more likely outside on cold days than old birds and young birds less likely outside on warm days compared to old birds. So, apart from the treatment effect, the photo and live observation afternoon data align in terms of age and temperature effects based on both datasets. More birds were ranging in the afternoon compared to midday, which aligns with range use in broilers and laying hens at this time of day (Reiter et al., 2006; Taylor et al., 2017).

The interactions between temperature and treatment, and temperature and bird age, suggest a benefit of silvopastures for younger birds on cold days, while a benefit from the silvopasture seems to exist for older birds on warm days. Our results suggest that the silvopasture in this study did not serve as a universally attractive environment, but rather, served specific functions dependent on ambient temperature and bird age. Our findings support the conclusion that silvopasture offers age- and temperature-dependent benefits for range use, but the extent of these benefits may depend on how range use is measured. Our study implies that observations from photos may not be a suitable method to determine range use, since photos likely underestimate the bird numbers. Bird numbers in the silvopasture photos may especially be underestimated because there is more vegetation that could obscure birds from sight of the observer. When observing live, we recorded more birds ranging in the silvopasture, confirming previously reported benefits of natural vegetation and cover for ranging behavior (Collias and Collias, 1967; Dawkins et al., 2003; Dal Bosco et al., 2014; Stadig et al., 2017a). The contrasting results from the photos in this regard are concerning and emphasize the importance of choosing a sampling strategy. Yet, relationships between age and ambient temperature were consistently found across both methods, suggesting that these are especially meaningful determinants of range use. Ensuring that broiler chickens have the choice to access the outdoor range, or remain indoors if preferred, represents an important benefit to their welfare.

Data availability statement

Data underlying this manuscript are made accessible through the Virginia Tech Data Repository at https://doi.org/10.7294/31036048.

Ethics statement

The animal study was approved by The Virginia Tech Institutional Animal Care and Use Committee (protocol 20-044). The study was conducted in accordance with the local legislation and institutional requirements.

Author contributions

LJ: Methodology, Funding acquisition, Conceptualization, Writing – original draft, Supervision, Project administration, Writing – review & editing, Investigation. BP: Writing – original draft, Investigation, Writing – review & editing. GB: Writing – review & editing, Writing – original draft, Formal analysis, Data curation, Visualization. AD: Conceptualization, Writing – review & editing, Funding acquisition, Resources. JM: Writing – review & editing, Funding acquisition, Conceptualization. JF: Writing – review & editing, Funding acquisition, Conceptualization. GP: Funding acquisition, Resources, Writing – review & editing, Conceptualization, Supervision.

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Conflict of interest

The authors declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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