ANIMAL WELL-BEING AND BEHAVIOR

Associations between weather conditions and individual range use by commercial and heritage chickens

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ABSTRACT Ranging area use by domestic poultry is not always optimal and differences in it exist on the levels of breed, flock and individual bird. Outdoor shelters are usually not protective for all weather parameters and may not fulfil a protective role to all birds within the flock all time, if individuals are sensitive to different weather conditions. The aim of this study was to investigate associations between different weather parameters and the use of the range by individual Green-legged Partridge and Sasso C44 chickens. In August 2018, 60 birds per genetic strain were housed in groups of 10 from wks 5 to 10, under conditions exceeding minimal EU requirements of organic meat chicken production. Birds in each pen had access to an outdoor range that was video-recorded during the experiment to obtain frequencies of individual birds' use of the ranges. Weather data were collected each minute throughout the whole experiment by an automatic weather station. In each pen, birds tagged individually with a laminated color tag, had access to an outdoor range that was video-recorded during the experiment. Frequencies of individual birds' use of the ranges were manually obtained from the recordings. Univariate and multivariate linear regression models were used to investigate the associations between the variables. The results showed significant associations between weather parameters and range use for one third of Green-legged Partridge and Sasso chickens (n = 21 in both breeds). Between breeds, range use associations with different weather parameters were identified. Negative associations with relative humidity occurred most frequently in Green-legged Partridges (n = 8; R^2 from 0.1 to 0.17), while positive associations with atmospheric pressure (n = 7; R^2 from 0.09 to 0.17) were most common in Sasso chickens. Further investigations into the reasons behind individual sensitivity of meat-purpose chickens to specific weather conditions would increase the understanding of their preferences and needs, which over time will improve animal welfare.

Key words: weather, organic, broiler, range, behavior

2021 Poultry Science 100:101265
https://doi.org/10.1016/j.psj.2021.101265

INTRODUCTION

The behavior, welfare and productivity of broiler chickens are influenced by the genetic makeup and environmental factors (Zuidhof et al., 2014). In conventional broiler production systems, birds are reared in strictly controlled indoor conditions (Lima and Nääs, 2005). Increased public concerns of animal welfare in those systems (Marchewka et al., 2013), including decreased ability of the poultry to express natural behaviors, has directed consumers' attention to meat from poultry reared in low-input systems, known as optimizing the management and use of internal production inputs and minimizing the use of production inputs (Biala et al., 2007; FAO, 2007; Erian and Phillips, 2017). In some systems, as for instance in the European organic systems, birds are provided with ranging area (EU, 2007, 2008).

Previous studies have shown that the ranging area use by broiler chickens is not always optimal and that differences exist not only on the flock or breed level, but also between individual birds in the same flock, even if equal opportunity of access to the range is provided (Dawkins et al., 2003; Taylor et al., 2017). Basic outdoor environmental factors which are likely to influence animal comfort are air temperature, relative humidity and speed of air movement (Dec et al., 2018). While rearing

Received January 26, 2021.

Accepted May 12, 2021.

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birds in an environment which promotes better comfort and therefore assures good animal welfare (Silva et al., 2003), the comfort zone related to weather parameters for free-range broilers has not yet been investigated (Santos et al., 2014).

In modern commercial free-range chicken production systems, outdoor ranges may have large open spaces and very little shelter. In order to promote the use of the ranging area by the birds, the facilities should protect the birds from adverse weather conditions by providing for instance sun shade or wind protection. However, available shelters may not be protective under all weather conditions, they may not fulfil their protective role in the particular geographical and climate zone or they may not be available to a sufficient number of birds in a flock at once when needed (Stadig et al., 2017). Better understanding of the motivation behind the ranging choices birds make, could help to improve the facilities provided to them.

One of the still unknown aspects is whether on an individual level birds' ranging activity is associated with the prevailing conditions. Most of the broiler studies to that, that have associated weather parameters with range use, have averaged across the breed or treatment group (Stadig et al., 2017; Taylor et al., 2017). However, individual birds in a flock reach outdoor areas at various time points that would have associated weather conditions specific to that particular moment. If individual birds react differently to the weather conditions, it would make an important argument in the discussion regarding design of ranging areas and need for the simultaneous use of the various weather protecting elements, such as: shrubs, trees, wind, and sun panels on the same range.

Only one study to date has focused on the within-flock variability, where individual ranging behavior of free-range broiler chickens was recorded using the radiofrequency identification system. However, in this study the weather variables predicted the total numbers of chickens in the flock that accessed the range (Taylor et al., 2017). Moreover, in the above-mentioned study, the weather parameters were collected every 10 min in the summer and twice a day in the winter, which did not allow exact matching of range access with instantly changing weather parameters such as wind speed. Therefore, to our knowledge no previous studies have investigated range use of individually identified birds within a broiler chicken flock across the production cycle and matched with the weather parameters collected in the exact same time points and location.

The aim of this study was to investigate associations between weather parameters and the frequency of the range area use by individual Green-legged Partridge and Sasso chickens. The Green-legged Partridge is an old native Polish breed characterized by green-colored shanks, which is well adapted to the local environmental conditions (Siwek et al., 2013). This breed is especially adequate for maintenance in extensive, outdoor access production systems, as characterized by good health and low prevalence of welfare issues (Marchewka et al., 2020). The average body weight of Green-legged Partridge roosters is around 2.5 kg and hens around 1.7 kg, which is achieved at about 5 mo of age. The slower growing chicken hybrid Sasso is widely and successfully used in the commercial production across the globe (Hendrix Genetics BV and Sasso, France). It is well skilled to forage on outdoor ranges and has been especially well adapted to various environmental conditions, from the European continental climate, as in the Label Rouge production system, to the African hot climate (Getiso et al., 2017). Sasso birds reach a slaughter weight of 2.3 to 2.8 kg at about 2 mo of age, while their meat is characterized by a very good taste and quality (Getiso et al., 2017). We hypothesized that higher relative humidity or wind speed may limit range use of individual Green-legged Partridge and Sasso chickens, while temperature increase, within the birds thermal comfort ranges may promote it.

MATERIALS AND METHODS

The experiment took place from the August 21 until September 22, 2018 in the Mazovian region in Poland, at the facilities of the experimental farm of the Institute of Genetics and Animal Biotechnology of the Polish Academy of Sciences.

Animals, Housing, and Management

Sixty mixed-sex, non-beak trimmed birds, of each of 2 breeds (total n = 120 birds), Green-legged Partridge and Sasso line C44 (for consistency, both Sasso and Green-legged Partridge will be referred to as "breed," although Sasso is a hybrid) were used in the experiment. Before wk 5 of age, birds were not allowed outdoor access. At the age of 5 wk, 120 birds were categorized as healthy by the veterinarian assigned to care for the animals in the experimental facility. Individuals with similar body weight within each breed (on average 2030.6 ± 68.9 g for Sasso and 705.9 ± 8.5 g for Green-legged Partridge), were selected and relocated from their rearing facilities, located at the same breeding station as the experimental house. Eight female and 2 male chickens were assigned to each single breed group housed in 12 pens until 10 wk of age. No birds died during the experiment. The size of the indoor pens was 2.5 m × 3.5 m, resulting in a stocking density at slaughter age of 1.4 kg/m^2 for Green-legged Partridge and 2.7 kg/m^2 for Sasso. Sawdust litter was added on top of the floor, while next to the wall there was a 0.5 m strip covered with sand. New litter was supplied weekly and pens were partly cleaned according to the need. In each pen, there were two 80-cm long wooden perches with 2 perching levels, one at the height of 15 cm and the second at 40 cm. The perching poles were 50 × 50 mm thick and had rounded edges. Each pen had direct access to an individual outdoor range (3.5 m × 30 m), through the pophole (45 cm high × 50 cm wide), providing 10.5 m^2/chicken. All the outdoor ranges had equal vegetation coverage regarding botanical composition and height but no trees or shelters were present. The grass was mowed 1 wk before the onset of the experiment. Each ranging area was provided a semiautomatic bell drinker and a wooden box (1 m × 1 m) filled with sand. The schematic figure representing the experimental facilities was presented in Marchewka et al. (2020).

After relocation, the birds were habituated for 48 h to the new housing and social situation before popholes were opened daily from 7.00 until 19.00 h. To allow for individual bird identification, all birds were fitted with a laminated paper mark (9 cm high × 7 cm wide) attached to the birds' back by fitting 2 elastic bands around its wings. Ten different colors of the marks were assigned in each pen randomly to the individual birds. Birds were equipped with their color mark during the entire experiment, and they were inspected twice a day to assure their health and welfare and control for any unpredicted events. Commercial pelleted feed (Agro-Handel Mirsk, Poland) was used to nourish the birds. The feed was composed of wheat, maize, sunflower expeller, pea, soybean expeller legumes mix, gruel corn, monocalcium phosphate, soybean oil, calcium carbonate (components proportions protected by the local manufacturer) with supplements (Marchewka et al., 2020). The dietary composition of the feed was designed to meet slow-growing birds' nutritional requirements under the organic production circumstances at the age between 5 and 10 wk of age. It contained 20% of protein, 5% of fat, 6% of fiber, 6.5% of ash, 1.05% of calcium, 0.82% of lysine, 0.65% of phosphorus, 0.34% of methionine and 0.16% of sodium. No coccidiostats or other medication was used. Feed and water were available ad libitum.

Birds were provided only natural light through uncovered windows as the room had no artificial lights. Light hours during the experimental period ranged from 12.7 h to 15.7 h/day. There was natural ventilation in the building. Indoor climate parameters were automatically and continuously collected by an add-on device of the main weather measuring device (Davis Instruments Vantage Pro 2 DAV-6152EU, CA) placed in the middle of the chicken rearing house on a height of 1 m.

Data Weather Collection

Weather data were collected once per minute throughout the whole experiment. An automatic weather station used for this purpose (Davis Instruments Vantage Pro 2 DAV-6152EU, CA) was installed at the end of the central ranging area, height of 1 m from the ground. The following parameters were collected: air temperature (°C) and relative humidity (%), wind direction (cardinal directions) and wind speed (m/s), atmospheric pressure (hPa) and the sum of daily precipitation (mm). These data were automatically saved in a Microsoft Excel spreadsheet (2016). For the purposes of statistical analysis, the cardinal directions of the wind were converted to degrees, where degree "0" indicated north wind (N), while interpretation of the increase in the degrees followed the standard compass rose.

Observations of Ranging Behavior

Ranging behavior of the birds was recorded using video cameras. The 12 outdoor pens were video-recorded simultaneously and continuously using 6 cameras (BCS company Poland-DMIP2401IR-M-IV IP 4 Mpix), each completely covering 2 ranging areas. The films were automatically saved on the network recorder (BCS-NVR0401-IP 4 channel BC). Video material was analyzed and bird location was recorded by the same trained and experienced person, using the Chickitizer program (Sanchez and Estevez, 1998). It is a computer application in which the presence of animals in predefined areas can be recorded with a single mouse click. The data from this application can easily be transferred to a calculation spreadsheet. From the recorded videos, 3 d were chosen per week of experiment (5 wk). On each of those days, 3 times of the day (morning: starting at 8:00, noon: starting at 13:00, and evening: starting at 18:00) a 3-min-period with 10 s sampling intervals was set and repeated after 10 min. In short, the observation protocol consisted of 6 samplings (1 sampling/10 s, making up to 1 min) * 3 min * 2 bouts * 3 times of day * 3 d each week * 5 wk. The observer recorded each of the experimental birds' absence as "0" or presence as "1 " in the outdoor area. Therefore, the frequency of individual outdoor use in the current study was between 0 and 1,620.

Statistical Analysis

In the simple and multiple regression models, the variable describing either the individual Green-legged Partridge or Sasso chicken range use (sum of the individual bird presences in the outdoor area during observation periods) was considered as the dependent outcome variable, while weather parameters at the time of the range use observations were considered as the independent variables: air temperature (°C) and relative humidity (%), wind direction (cardinal directions) and wind speed (m/s), atmospheric pressure (hPa) and the sum of daily precipitation (mm). The outcome variable was analyzed for associations with any of the independent variables. The outcome variable was normally distributed across the sample population, thus linear univariate regression was used. Residuals were predicted and checked for normality. Associations with P-value <0.2 were further analyzed in a multivariate linear regression analysis. Models were backward exclusion until all associations reached P-value <0.05. Interactions between independent variables were tested in the final models and were not detected. Residuals were predicted and plotted in normal quantile plots and coefficients of determination (R^2) were calculated and used to choose the model that explains the variability of the response data. The likelihood ratio test was used to observe the improvement of the multiple regression models by inclusion and exclusion of independent variables. Akaike's information criterion and Schwarz's Bayesian information criterion were used to compare maximum likelihood of reduced

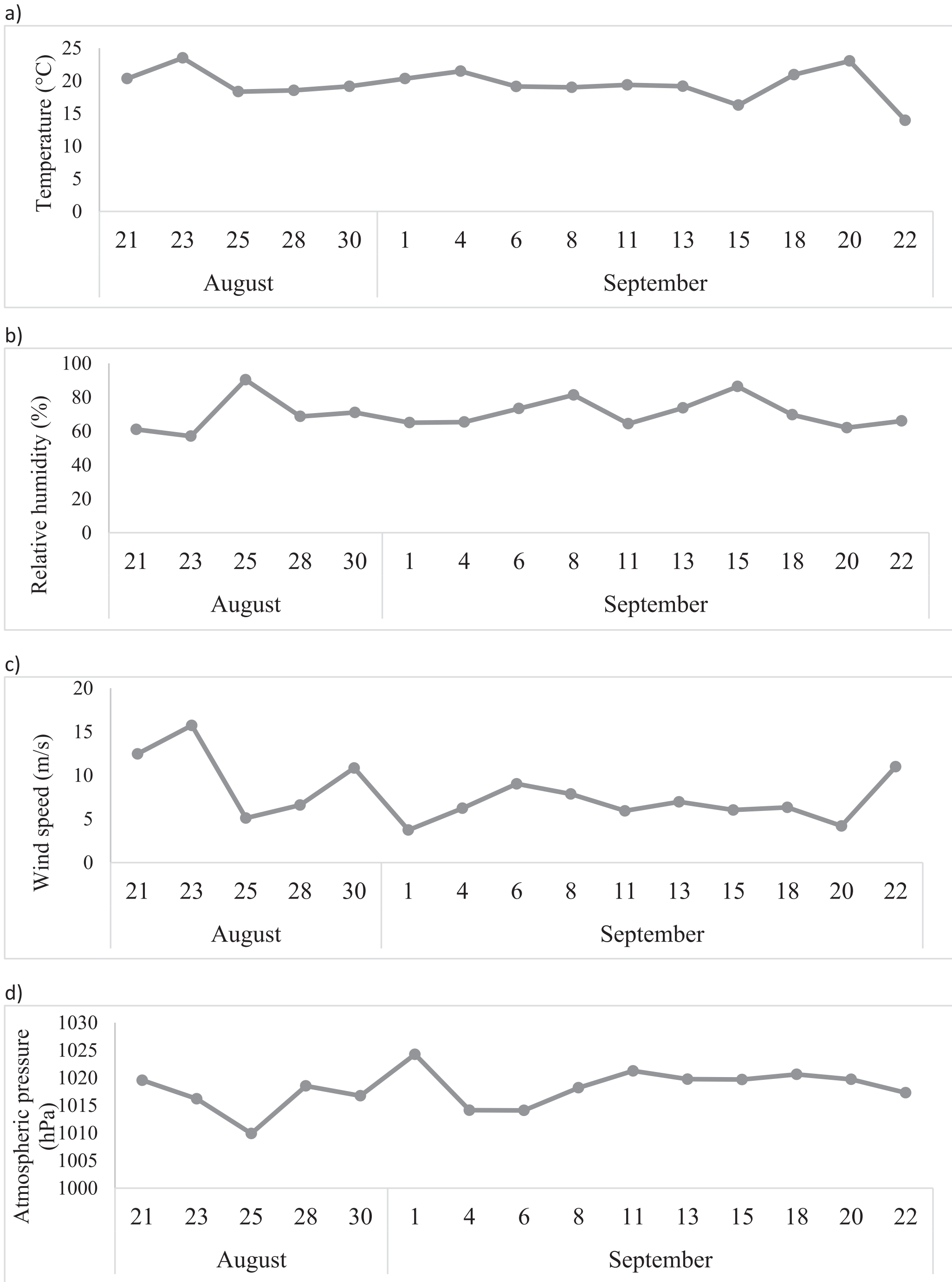

Figure 1. Outdoor weather parameters recorded during the behavioral observation periods and averaged per observation day; (A) temperature; (B) humidity; (C) wind speed; (D) atmospheric pressure.

and full models. The selection of the final models was based on the smaller values of the information criterion.

RESULTS

The temperature recorded in the building during the experiment ranged from 19°C to 26°C, while relative humidity ranged from 47 to71%. During the day, outside temperature ranged from 12°C to 28°C, outside relative humidity from 46 to 99%, wind speed from 0 to 24 m/s and atmospheric pressure from 1,004 hPa to 1,027 hPa (Figure 1A−1D). The dominating wind direction was western and south - western (Figure 2).

Associations Between Weather Parameters and Range Use by Individual Green-Legged Partridge Chickens

The results of the simple and multiple regression models showing associations between range use by individual Green-legged Partridge chickens and weather parameters are presented in Table 1 together with the mean

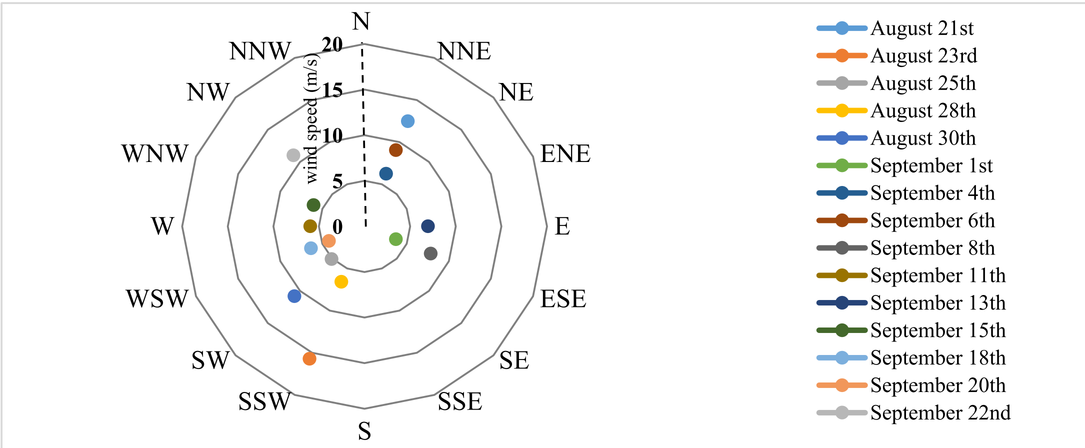

Figure 2. Wind direction recorded during the behavioral observation periods per observation day presented in cardinal directions. Each day is marked on the graph with a different color and for each day, the average wind speed is indicated. *Collected data of cardinal directions were first converted to degrees, where degree "0" indicated north wind (N), interpreted following the standard compass rose and averaged for each day, afterwards reconverted to the cardinal directions.

frequency and standard deviation of the range usage by the birds. Significant associations between the range uses with one weather parameter were identified for 20 birds, while with 2 weather parameters for one bird. For the remaining 39 birds, no significant associations were identified between individual range use and weather parameters.

Increased range use of 8 birds was significantly and positively associated with relative humidity, where the proportion of explained variance of the response variable ranged from 10 to 17%. Range use of 3 birds was positively associated with temperature and also for three birds with wind direction expressed in degrees. The proportion of variance of range use explained by the temperature ranged from 12 to 20%, while for wind direction from 9 to 16%. Atmospheric pressure was positively associated with the range use of 3 birds, while one bird used the ranges less often when the atmospheric pressure increased (negative association). In case of 2 birds, an association between higher wind speed and reduced range use was identified. Moreover, the range use of one bird was associated with 2 weather

Table 1. Associations between free range use by individual Green-legged Partridge chickens and different weather parameters.

									Individual free range use	
Weather parameter	R^2	Parameter estimate (r)	SE	T Value	Pr > |t|	95% Confidence	Limits	Pen	Mean/ day	SE
Simple linear regression models (n = 20)										
Atmospheric pressure (hPa)										
	0.13	0.98	0.41	2.40	0.02	0.16	1.80	1	9.29	1.49
	0.11	0.68	0.30	2.28	0.03	0.08	1.28	2	4.33	1.08
	0.11	0.95	0.41	2.30	0.03	0.12	1.78	3	12.49	1.50
	0.09	−0.53	0.26	−2.05	0.05	−1.06	−0.01	5	3.44	0.93
Relative humidity (%)										
	0.15	−0.19	0.07	−2.66	0.01	−0.33	−0.04	1	7.22	1.21
	0.12	−0.14	0.06	−2.41	0.02	−0.26	−0.02	2	2.93	1.01
	0.10	−0.16	0.08	−2.13	0.04	−0.31	−0.01	2	6.98	1.27
	0.15	−0.18	0.07	−2.67	0.01	−0.31	−0.04	3	7.49	1.17
	0.17	−0.19	0.07	−2.91	0.01	−0.33	−0.06	3	9.44	1.17
	0.12	−0.17	0.07	−2.36	0.02	−0.32	−0.02	4	8.00	1.45
	0.12	−0.20	0.08	−2.32	0.03	−0.37	−0.03	4	5.51	1.23
	0.16	−0.24	0.09	−2.75	0.01	−0.42	−0.06	6	7.22	1.21
Temperature (°C)										
	0.20	1.19	0.38	3.17	0.00	0.43	1.95	1	11.13	1.64
	0.13	0.86	0.35	2.46	0.02	0.16	1.57	3	7.64	1.44
	0.12	0.99	0.41	2.40	0.02	0.16	1.82	6	13.56	1.72
Wind direction (°)										
	0.16	0.03	0.01	2.86	0.01	0.01	0.06	1	7.13	1.41
	0.09	0.02	0.01	2.15	0.04	0.00	0.04	2	5.00	1.14
	0.15	0.03	0.01	2.71	0.01	0.01	0.06	5	6.36	1.28
Wind speed (m/s)										
	0.12	−0.54	0.22	−2.41	0.02	−0.99	−0.09	5	4.80	0.95
	0.15	−0.62	0.23	−2.70	0.01	−1.09	−0.16	5	5.78	1.01
Multiple regression model (n = 1)										
Relative humidity (%)	0.33	−0.31	0.08	−4.03	0.00	−0.46	−0.15	1	9.60	1.23
Wind direction (°)		0.03	0.01	2.28	0.03	0.00	0.05			
No model selected (n = 39)	Not applicable							1-6	7.83	0.46

Table 2. Associations between free range use by individual Sasso chickens and different weather parameters.

									Individual free range use	
Weather parameter	R^2	Parameter estimate (r)	SE	t Value	Pr > |t|	95% Confidence	limits	Pen	Mean/day	SE
Simple linear regression models (n = 19)										
Atmospheric pressure (hPa)										
	0.09	0.93	0.46	2.05	0.05	0.01	1.85	8	8.36	1.64
	0.10	0.97	0.45	2.15	0.04	0.06	1.89	9	11.09	1.65
	0.19	0.49	0.19	2.43	0.02	0.07	0.90	10	1.21	0.88
	0.15	0.81	0.38	2.11	0.04	0.02	1.60	10	4.00	1.66
	0.16	0.71	0.33	2.17	0.04	0.04	1.39	10	6.43	1.44
	0.17	1.18	0.40	2.94	0.01	0.37	1.99	11	7.09	1.51
	0.11	1.01	0.44	2.32	0.03	0.13	1.90	11	9.82	1.60
Relative humidity (%)										
	0.14	−0.23	0.09	−2.57	0.01	−0.42	−0.05	8	12.16	1.60
	0.09	0.05	0.02	2.08	0.04	0.01	0.09	12	0.56	0.39
Temperature (°C)	Not applicable									
Wind direction (°)										
	0.11	−0.03	0.01	−2.31	0.03	−0.06	−0.01	8	6.84	1.51
	0.16	0.04	0.01	2.80	0.01	0.01	0.07	8	7.18	1.65
	0.21	0.04	0.01	3.38	0.01	0.02	0.06	8	6.36	1.38
	0.13	−0.02	0.01	−2.54	0.02	−0.03	−0.01	9	2.69	0.86
	0.12	0.03	0.01	2.44	0.02	0.01	0.05	9	10.13	1.43
	0.11	0.04	0.02	2.27	0.03	0.01	0.07	12	12.73	1.89
	0.20	0.03	0.01	3.27	0.01	0.01	0.06	12	7.76	1.31
Wind speed (m/s)										
	0.09	−0.71	0.35	−2.03	0.05	−1.40	−0.01	8	8.38	1.54
	0.11	−0.64	0.28	−2.31	0.03	−1.20	−0.08	11	7.40	1.25
	0.11	−0.51	0.23	−2.23	0.03	−0.97	−0.05	11	4.44	1.03
Multiple regression model (n = 2)										
Wind speed (m/s)	0.23	−0.82	0.34	−2.43	0.02	−1.51	−0.14	9	7.87	1.61
Atmospheric pressure (hPa)		0.91	0.42	2.16	0.04	0.06	1.75			
Relative humidity (%)	0.35	−0.25	0.09	−2.56	0.01	−0.45	−0.05	8	13.58	1.75
Wind speed (m/s)		−1.22	0.38	−3.24	0.00	−1.99	−0.46			
Wind direction (°)		0.04	0.03	3.05	0.00	0.01	0.04			
No model selected (n = 39)	Not applicable							7-12	5.12	0.69

parameters: negatively with relative humidity and positively with the wind direction, where the proportion of explained variance of the response variable by those weather parameters reached 33%.

Associations Between Weather Parameters and Range Use by Individual Sasso Chickens

The results of the simple and multiple regression models showing associations between range use by individual Sasso chicken and weather parameters are presented in Table 2. together with the mean frequency and standard deviation of the range usage by the birds. The significant associations of the range use with one basic weather parameter were identified for 19 birds, with 2 and 3 basic weather parameters each for 2 Sasso birds. No significant associations were identified between individual range use and weather parameters for the remaining 39 birds.

Both atmospheric pressure and wind direction were associated with range use of 7 birds. Atmospheric pressure was positively associated with range use (between 9 and 17% of variance explained), while range use was either negatively or positively associated with the wind direction (between 11 and 21% of response variable variance explained). In the case of three Sasso birds, wind speed was negatively associated with the range use frequency. Inconsistent associations between range use and relative humidity were found, as it was negative for one bird and positive for another bird. Moreover, the range use of one bird was associated with two weather parameters: negatively with wind speed and positively with the atmospheric pressure, where the proportion of explained variance reached 23%. In the case of one bird, association with three weather parameters was identified (relative humidity, wind speed and wind direction), which explained 35% of the range use variance.

DISCUSSION

A free-range systems provide animals with the choice when, where, and how they spend the time. Monitoring these choices can permit an understanding of what free-range broiler chickens want, which is an integral part of defining and safeguarding welfare (Dawkins, 2004). The current study was developed to answer a question on how range use of individual chickens is associated with the weather conditions. Following the undertaken approach of the individual bird' range use analysis, the birds' behavior was matched precisely in time with the weather parameters collected each minute. If individual birds in the same flock react differently to the weather conditions, it would make an important argument in the discussion regarding the need for the simultaneous use of various weather protecting elements on the range to promote range use.

Better understanding of chicken ranging behavior could help to improve management and range design, to ensure optimal ranging opportunities but also optimal productivity and welfare of the birds (Taylor et al., 2017). Previous studies indicated that broiler chicken ranging behavior is affected by the time of the day, weather variables (rainfall, direct sunlight, temperature, and wind speed) and resources on the range (e.g., trees and straw huts) (Dawkins et al., 2003; Nielsen et al., 2003; Jones et al., 2007; Rivera-Ferre et al. 2007; Stadig et al., 2017). However, how such parameters affect ranging patterns of individual broiler chickens has not been reported. The primary reason is that still limited technology is available that is noninvasive, reliable and feasible enough for long-term tracking an individual chicken's precise location, especially in outdoor conditions of a commercial farm (Siegford et al., 2016). However, focus on the individual ranging chickens, as compared to flock level behavior analysis, has recently proven to be very important. Recent investigations using methods of monitoring individual broiler chicken ranging behavior suggested that 75 to 95% of chickens in a flock accessed the range (Durali et al., 2014; Taylor et al., 2017), as compared to the 3% to 27% of birds in a flock accessing the range as noted during scan observations at the flock level (Rodriguez-Aurrekoetxea et al., 2014; Fanatico et al., 2016).

The choice of Green-legged Partridge or Sasso chicken breeds in the current experiment allowed us to minimize the risk of birds not using the ranges due to poor health reasons, for instance mobility issues. Results from the present study confirmed low occurrence of such health issues (see Marchewka et al., 2020).

The proportion of variance explained by the weather parameters in range use ranged between 9% and 35%. Even though such levels of variance explained may not be considered important in predictive type of studies, they may be considered as a meaningful part of variance in associative studies such as the current one (Pedhazur, 1997).

Associations of birds' range use with weather conditions were distributed across all recorded weather parameters, however differently for Green-legged Partridges and Sasso. The weather parameter that the range use of Green-legged Partridge birds was most often associated with was relative humidity outdoor. The association was negative, which is in agreement with previous studies in layers, where more laying hens ranged away from the shed when the relative humidity level was low, i.e. on cooler days and with no rainfall (Gilani et al., 2014), while use of the outdoor areas was reduced in wet weather (Mirabito and Lubac, 2001; Hegelund et al., 2005; Gilani et al., 2014). Broilers tend to avoid wetting the feathers, which decrease their thermal comfort and requires higher time investments in preening (Huber-Eicher and Wechsler, 1998).

Such negative association of ranging with relative humidity was identified only for one Sasso bird, indicating higher resilience of those birds to this condition. Sasso has been described as having the genetic potential of tropically adapted birds (Yakubu et al., 2018), where the hot season in the tropics is characterized by periods of high temperatures and high relative humidity, which can be compared to some extent to the weather conditions in August and September of 2018 in Poland, especially in the mornings. The large combs of Sasso birds were suggested to be an adaptive feature that might function as a biological heat exchanger (Yakubu et al., 2018), facilitating evaporative cooling of the brain; a feature to maintain thermal homeostasis when birds are exposed to high environmental temperature and relative humidity (Gerken et al., 2006).

Ranging behavior of seven Sasso birds was positively associated with the atmospheric pressure, as compared to three Green-legged Partridges. It is well known that birds can sense changes in barometric pressure (Paige, 1995). Higher atmospheric pressure in moderate warm climate, as in Poland, is usually associated with no precipitation and weak wind conditions, which are preferred by the chickens, as opposed to humid and windy weather (Nielsen et al., 2003; Jones et al., 2007). Nevertheless, the exact explanation as to why Sasso would be more sensitive to atmospheric pressure in relation to ranging behavior remains unclear.

In the current experiment, we identified that ranging behavior of ten birds was associated with wind direction, out of which seven birds were Sasso and three were Green-legged Partridges. Moreover, in five other birds, three Sasso and two Green-legged Partridges, ranging was associated with the wind speed. Wind is a complex atmospheric phenomenon, which affects animals in many dimensions. In flying birds, the light and often variable winds enable migrant birds to fly with little risk of drift from its preferred heading or track (Van Doren et al., 2016). Wind, especially strong or gusty, can distract bird's vigilance, as the amount of stimuli in the background increases, which can cause birds to feel more endangered by predators and look for shelter or even stay indoors (Nicol, 2015). In our experiment, the range use of the Green-legged Partridges increased when the wind blew from the SSW, SW, WSW and W directions. In the Polish climate, such wind directions are related to mostly mild and warm air blows, but also characterized by low speed which seemed favorable by the Green-legged Partridges

Range use of three Green-legged Partridges was positively associated with air temperature, while surprisingly this association was not observed for any of the Sasso birds. Air temperature higher than 26°C has been described as unfavorable for the activity and comfort of domestic poultry (Etches et al., 2008; Mignon-Grasteau et al., 2015). During the current experiment, the outdoor air temperature at the observation time points did not exceed maximum of 28°C degrees, however the average air temperature measured at the behavioral observation points was 19.6 ± 0.6°C, which is within known poultry thermal comfort range for birds of that age (Pereira and Naas, 2008). Higher air temperature is often associated with more sunshine. In broilers outdoor shelter effectively encouraged chickens to use the range area under increasing solar radiation (Stadig et al., 2017). If no shelter would be present and birds' attempts to seek shady areas to cool down were unsuccessful, it may result in birds remaining indoors (Stadig et al., 2017). Therefore, we may assume, based on the current results, that ranging behavior of the three Green-legged Partridge chickens positively associated with the air temperature indicated that individuals may have variable thermal preferences, probably as long as the upper level of the thermal comfort zone is not exceeded. Moreover, as stated above, Sasso may overall be more adapted to higher air temperatures, due to their genetic makeup (Gerken et al., 2006).

For three birds in the current study multiple regression models were identified, which could provide some preliminary indications regarding weather parameters, which combined are assuring the thermal comfort of ranging chickens. Range use of one Green-legged Partridge chicken was negatively associated with relative humidity and positively with the wind direction. In Sasso, one model included wind speed and atmospheric pressure, while another one included relative humidity, wind speed and wind direction. Those models explained between 23% up to 35% of the variance in response variable. Wind is air pressure converted into movement of air. When air slows down, its pressure increases (Tweel and Turner, 2014). Even though those two measurements in the current study were not correlated when selecting the dependent variables to be tested by regression analysis, interpretation of this multiple regression model should be done with caution.

The birds' choice to venture outside may have been instigated by either positive or negative motivation. For instance, chickens may access the outdoor range to explore a more complex environment than the typical indoor shed environment, but, on the other hand, they may try to avoid negative uncomfortable, frightening, or painful stimuli, either in the shed or outdoors (Taylor et al., 2017). The ranging behavior of the two third of the birds in this experiment was not associated, either negatively or positively with the collected weather parameters. Surprisingly, in both breeds this proportion of individuals was the same. Interestingly, these individuals used the ranging areas on a similar frequency level as the remaining birds in the experiment. Understanding the motivations behind the ranging behavior of this group of birds, for instance reactions to contrast in climate between indoor and outdoor environment, requires further investigations, with consideration of other types of underlying factors than weather conditions, such as birds health status, indoor housing environment, birds stocking density or group size.

Producers have only limited possibilities to reduce the impact of weather conditions on chickens reared in low-input systems with range access, while optimizing their range use. However, certain structures such as wind, rain or humidity protections can be applied on the outdoor areas. Positive effects of motivating more birds to use the areas away from the house by providing natural and artificial wind protections and covers have been shown in layers (Zeltner and Hirt, 2003). Furthermore, it has been found that planting shrubs, trees or using other forms of shading improved the use of ranges by chickens, by protecting them against sun and predators (Stadig et al., 2017). As a step to convince free-range meat-purpose chicken producers to implement strategies encouraging their birds to use the outdoor areas more, we have presented evidence that birds react individually to the same weather conditions. Therefore, we suggest designing ranging areas such that they accommodate individual preferences/needs, for example, by including provision of multiple construction and vegetation elements.

In conclusion, we found significant associations between different weather parameters and the individual use of the ranges for approximately one third of Green-legged Partridge and Sasso chickens. Between breeds, the associations to the particular weather parameters were different, with relative humidity occurring most frequently in Green-legged Partridges, while air pressure and wind direction were most common in Sasso. Further investigations into the reason behind increased sensitivity of some commercial and heritage meat-purpose chickens to particular weather conditions would be beneficial for a better understanding of their needs, which over time will improve animal welfare.

ACKNOWLEDGMENTS

This work was funded within the project entitled: Optimising the use of the ranges as the key to improve organic chicken production; Acronym: “FreeBirds” under Coordination of European Transnational Research in Organic Food and Farming System Cofund (CORE Organic Cofund) by the European Union’s Horizon 2020 research and innovation programme under grant agreement No. 727495. We would like to thank The National Centre for Research and Development in Poland for help in managing and executing this project under agreement No. COREORG/COFUND/FREEBIRDS/2/2018. The authors would also like to thank technicians, students and animal caretakers for their work during the project.

DISCLOSURES

The authors have no conflicts of interest to disclose.

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