Associations between welfare and ranging profile in free-range commercial and heritage meat-purpose chickens (*Gallus gallus domesticus*)

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ABSTRACT Despite consumers' belief that access to an outdoor range improves chicken welfare, still little is known about whether this is true and whether individual ranging profiles relate to the birds' welfare. The aim of the present study was to identify and compare welfare issues of the traditional broiler hybrid Sasso and the Polish heritage chicken Green-legged Partridge, having outdoor access, and examine if the birds' welfare status was associated with the ranging profile: outdoor-preferring, moderate-outdoor, and indoor-preferring. In August 2018, 60 non-beak trimmed birds per genetic strain were housed in groups of 10 from weeks 5 to 10, under conditions exceeding EU requirements of organic meat chicken production. Each pen had access to an individual outdoor range that was video-recorded continuously to obtain frequencies of individual birds' use of the ranges. Plumage condition, comb pecking wounds, skin injuries, dirtiness, toe damage, eye pathologies, footpad dermatitis, hock burns, respiratory infections, diarrhea, and walking difficulties were assessed at the end of the experiment. Statistical analysis was conducted applying generalized linear mixed models, with binomial distribution and logit link using SAS software, applying breed and ranging profile as fixed factors and their interaction, with pen as random factor. A tendency for more respiratory infections was observed in Sasso birds from each ranging profile, as compared to matching ranging profiles presented by Green-legged Partridges (outdoor-preferring: $P = 0.0012$; moderate-outdoor: $P < 0.0001$; and indoor-preferring: $P = 0.0247$). Indoor-preferring Green-legged Partridges tended to present more respiratory infections, as compared to the 2 other ranging profiles within the breed (outdoor-preferring: $P = 0.0291$; moderate-outdoor: $P = 0.0448$). Regardless of the breed, toe damages were more frequent in indoor-preferring birds, as compared to other ranging profiles ($P = 0.017$). It remains unknown whether the use of outdoor areas prevents development of welfare issues or if birds with a suboptimal welfare condition become indoor-preferring individuals.

Key words: free range, broiler, ranging profile, animal welfare, organic

2020 Poultry Science 99:4141–4152
https://doi.org/10.1016/j.psj.2020.05.044

INTRODUCTION

Breeding poultry for fast growth with very efficient feed conversion rates has resulted in unwanted side effects on birds' health, welfare, and meat quality (da Silva et al., 2017; Hartcher and Lum, 2020). Increased public concerns of animal welfare has directed consumers' attention to meat from poultry reared in low-input systems, considered by them to be more sustainable and superior for bird welfare (Erian and Phillips, 2017). In low-input systems, housing and management aim for optimizing health and welfare of chickens, for example, by setting limits on flock size and stocking densities. In some selected systems, as for instance the European organic system, birds are also provided with ranging area (EU, 2008).

Despite the widespread consumers' belief that access to an outdoor range improves chicken welfare in general

Received March 31, 2020.
Accepted May 26, 2020.
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(de Jonge and van Trijp, 2013), still little is known about whether this is true. Few studies, as compared to laying hens, describe ranging behavior of meat-purpose chickens, while there are important differences between the 2 types (Dawkins, 2003). Recently, relationships between ranging behavior and welfare of Ross 308 chickens, including improvements in breast plumage cover, gait scores, and cardiovascular function, and a reduction in weight were identified (Taylor et al., 2018).

To assure positive welfare of free-ranging birds, breeds or hybrids should be chosen considering their ability to use the outdoor areas or pastures (ACMF, 2011; AECL, 2012). Slower-growing broilers are better able to use the resources provided by the free-ranging areas, allowing performance of natural behaviors such as foraging or dustbathing, compared to conventional fast-growing broiler breeds (Riber et al., 2018). Slower-growing broilers are also known to suffer less from physical restrictions and health issues, as compared to fast-growing hybrids of meat poultry (Bergmann et al., 2017). Nevertheless, the use of the outdoor range and its association with the welfare condition in various slower-growing broiler chicken breeds may vary.

Based on previous studies in laying hens (Rodriguez-Aurrekoetxea and Estevez, 2016), domestic poultry is likely to differ in its individual levels of free-range use. Moreover, not all broiler chickens access the outdoor range when the opportunity is provided, indicating potential individual variation within flocks (Durali et al., 2012; Taylor et al., 2017). Campbell et al. (2016) profiled individual laying hens, differing in their ranging profiles, as outdoor-preferring, moderate-outdoor, and indoor-preferring. This profiling attempt has not been performed in meat-purpose chickens yet, and it has not been determined, neither for layers nor for broilers, whether the ranging profiles are associated with the individual birds' welfare. This information could help to optimize the selection of birds with profiles best suited for free-range conditions, improving animal welfare.

The aim of the present study was to identify and compare welfare issues of the broiler hybrid Sasso (Hendrix Genetics BV and Sasso) used widely in the commercial production with Green-legged Partridge, a heritage breed of chicken indigenous to Poland (Siwek et al., 2013), both provided access to outdoor ranges. Furthermore, we examined if the birds' welfare status was associated with their ranging profile: outdoor-preferring, moderate-outdoor, and indoor-preferring. We hypothesized, that the welfare of outdoor-preferring birds was overall higher, as compared to birds presenting moderate-outdoor and indoor-preferring profiles.

MATERIAL AND METHODS

The experiment took place in Mazovian region in Poland in August-September of 2018, at the facilities of the experimental farm of Institute of Genetics and Animal Breeding of the Polish Academy of Sciences.

Animals, Housing, and Management

Sixty non-beak trimmed, mixed-sex birds of each of 2 breeds (total n = 120 birds), Green-legged Partridge and Sasso (for consistency, both Sasso and Green-legged Partridge will be referred to as "breed," although Sasso is a commercial hybrid), were used in the experiment. The Green-legged Partridge is an old native Polish breed, characterized by green-colored shanks (Krawczyk, 2009; Siwek et al., 2013). The average body weight of roosters is around 2.5 kg and hens around 1.7 kg, which is achieved at about 5 mo of age. In comparison, Sasso birds reach a slaughter weight of 2.3–2.8 kg at about 2 mo of age. Sasso birds are well skilled to forage on the outdoor ranges, having high resistance to low temperatures and diseases, while the meat is characterized by a very good taste and quality (Getiso et al., 2017). Before week 5 of age, birds were not allowed outdoor access. At the age of 5 wk, 120 healthy birds, as assessed by the experimental facilities veterinarian, with similar body weight within each breed (on average 2030.6 $\pm$ 68.9 g for Sasso and 705.9 $\pm$ 8.5 g for Green-legged Partridge), were selected and moved from their rearing facilities, located at the same breeding station to the experimental house. The birds were randomly assigned to the mixed sex, single breed groups of 10 birds housed in 12 pens where they were housed until 10 wk of age. Mortality was recorded during the experiment, but no birds died. The housing conditions were according to EU requirements of organic meat-purpose chicken production (EU, 2008). Indoor pens were 2.5 m $\times$ 3.5 m large, 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. A layer of sawdust litter was added on top of the floor, while next to the wall there was a 0.5 m stripe covered with sand. The litter was renewed weekly and pens were partly cleaned daily, according to the need. In each pen, there were two 80 cm long perches with 2 perching levels, one at the height of 15 cm and the second at 40 cm, respectively. Each pen had direct access to an individual outdoor range (3.5 m $\times$ 30 m), through the pophole (45 cm high $\times$ 50 cm wide), providing 10.5 m^2/chicken, thus considerable above the required 4 m^2/chicken in the organic systems. 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 free-range area was provided a half-automatic drinker and a wooden box (1 m $\times$ 1 m) filled with sand. The outline of the experimental facilities is presented in Figure 1.

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 birds' recognition, all birds were fitted with a small, laminated paper mark 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.

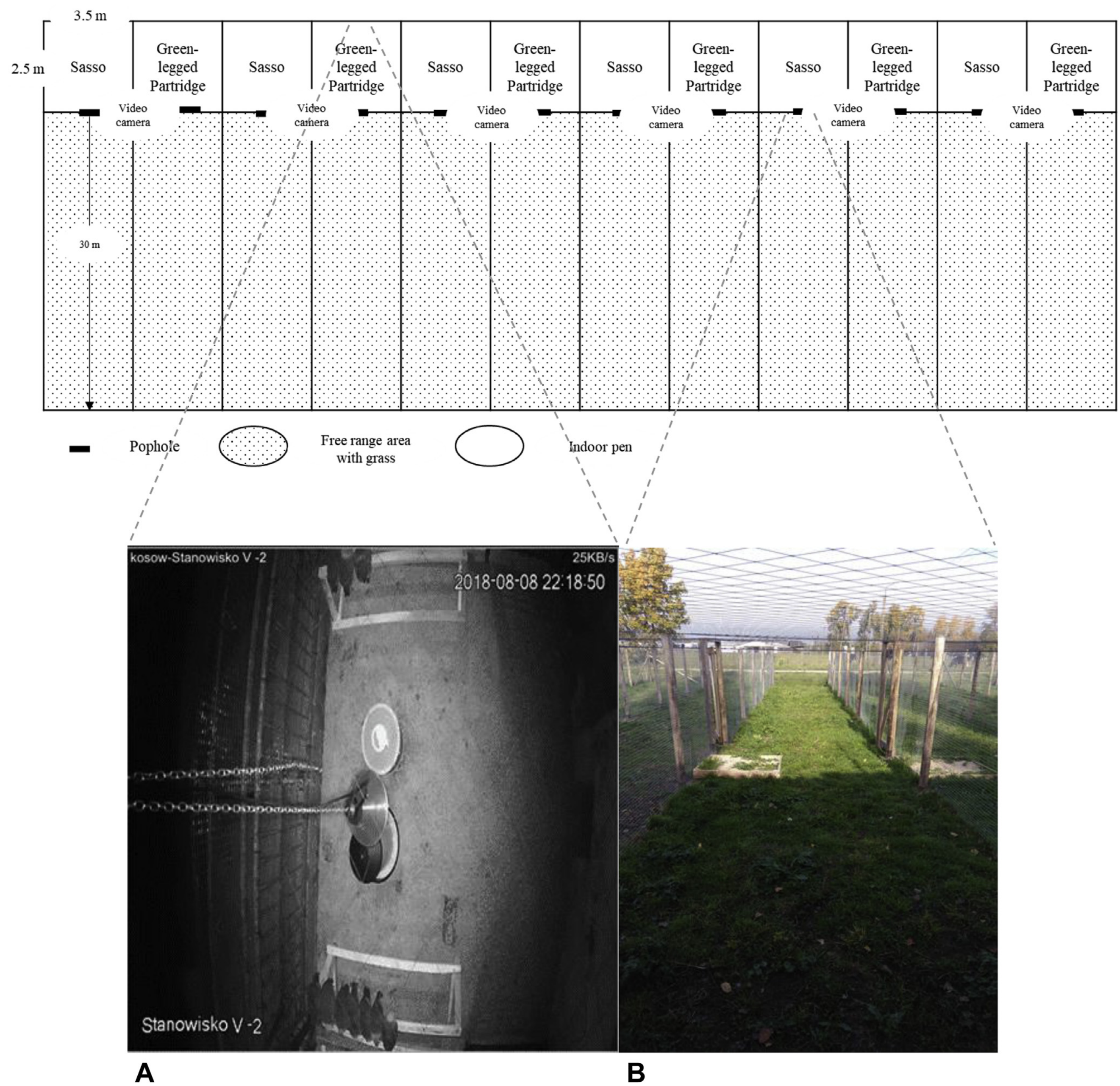

Figure 1. Experimental broiler chicken shed, pens, and range area dimensions with popholes and video cameras location. (A) night-time image of the Green-legged Partridge pen; (B) image of one of the free-ranging areas covered with vegetation and with sand box in the left side of the ranging area.

Birds were fed with a commercially available pelleted organic type of diet composed of wheat, maize, soybean expeller, sunflower expeller, pea, legumes mix, gruel corn, calcium carbonate, monocalcium phosphate, soybean oil (components proportions protected by the local manufacturer) with supplements as presented in the Table 1. All the components in the feed may be used in organic production in accordance with EU regulations (EU, 2007; 2008).

The chemical composition of the feed was designed to meet birds' nutritional requirements (Table 1). No coccidiostats or other medication were used. Feed and water were available *ad libitum* from pan feeders and half-automatic drinkers, respectively.

Birds were provided only natural light through uncovered windows and the room had no artificial lights. Light hours during 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 a measuring device (Davis Vantage Pro, Hayward, CA). The temperature recorded in the building during the experiment ranged 19°C–26°C, while humidity ranged 47–71%. During the day, outside temperature ranged 12°C–28°C, outside humidity ranged 46–99%, and wind speed 0–24 m/s.

Observations of Ranging Behavior

For behavioral observations of birds, the 12 outdoor areas were video-recorded simultaneously and continuously using 6 cameras (BCS-DMIP2401IR-M-IV IP

Table 1. The amount of the supplemented ingredients and chemical composition of the feed provided to the chickens during the experiment.

Feed composition	Amount
Supplements (per kg of feed)	
Vitamin A	10,000 units
Vitamin D3	1,500 units
Magnesium	79 mg
Iron	70 mg
Zinc	55 mg
Vitamin E	30 mg
Copper	15 mg
Iodine	1 mg
Selenium	0.2 mg
25-Hydroxycholecalciferol	0.03 mg
Chemical composition of the feed (%)	
Protein	20
Fat	5.1
Fibre	5.9
Ash	6.5
Calcium	1.05
Lysine	0.82
Phosphorus	0.65
Methionine	0.34
Sodium	0.16
11.8 MJ metabolic energy/kg	

4 Mpix), each covering completely 2 free-range areas. The recordings were automatically saved on the network recorder (BCS-NVR0401-IP 4 channel BC). The films were automatically saved on the network recorder (BCS-NVR0401-IP 4 channel BC). Video recordings were analyzed and bird behaviors were recorded by the same trained and experienced person, using the Chickitizer program (Sanchez and Estevez, 1998). The program is a computer application specially developed to record data about location of animals in enclosed, predefined areas, as it enables graphic mapping of the experimental layout (distribution of compartments) with a single mouse click. From the recorded videos, 3 D were chosen per week of experiment (5 wk), selected to avoid the day on which welfare assessment took place. On each of those days at 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. The observer recorded each of the experimental birds' absence as "0" or presence as "1" in the outdoor area.

Welfare Assessment

The welfare of each of the birds was assessed the day before the end of the experiment. There were 3 persons involved in welfare assessment, each assigned with a different task: 1) identifying (indicated by the color tag), catching, and weighing (using an automatic scale) the birds, 2) assessing the welfare indicators of the birds, and 3) noting the collected information in a spreadsheet. A description of the welfare indicators used in the present study is presented in Table 2. Plumage condition, comb pecking wounds, skin injuries, dirtiness, toe damage, eye pathologies, footpad dermatitis (**FPD**), and hock burns were scored on the scale 0 to 2, where "0" meant optimal condition, "1" minor negative deviation from the optimum condition, while "2" indicated major deviation from the optimum condition, as described in Welfare Quality protocol (Butterworth et al., 2009). Respiratory infections and diarrhea were scored as present "1" or absent "0." We did not observe any bird coughing and sneezing throughout the experimental period, whereas most birds scored with present respiratory infection had signs of respiratory effort usually with audible breathing sounds. The birds' walking ability was assessed using the gait scoring method presented in the Welfare Quality protocols for poultry (Kestin et al., 1992), in which the bird's gait is graded between 0 (perfect walking) to 5 (unable to move); however, owing to lack of representation and to allow more clear presentation of the scoring outcomes, the intermediate scores (1 and 2) were merged as "1"—minor negative deviation from the optimum condition and the higher scores (3, 4, and 5) as "2"—major deviation from the optimum condition. This study was not considered to be an animal experiment under the EU Law on Animal Experiments, since it followed regular farming procedures, and no bird was exposed to injections, surgical operations, or any other severe treatment.

Statistical Analysis

All the welfare indicators, regardless of original scoring scale, were transformed into present/absent format, where any score different from "0" was exchanged to "1." We decided to perform this transformation of the data due to the overall relatively low prevalence of scores different than "0." All below described analysis was performed based on 0/1 formatted data.

We divided all the birds used in the experiment into 3 ranging profiles using rank-frequency distribution (a discrete form of a quantile function in reverse order, giving the size of the element at a given rank). All the birds were assigned a rank based on their individual frequency of outdoor use. We segmented the rank distribution of the birds into 3 ranges: outdoor-preferring ranging profile (n = 33 birds) with the mean value of 489.32 ± 15.77 outdoor uses per bird; moderate-outdoor ranging profile (n = 49) with the mean value of 290.98 ± 6.83 outdoor uses per bird outdoor uses per bird; and indoor preferring ranging profile (n = 38) with the mean value of 95.73 ± 9.42 outdoor uses per bird. The rank intervals were equal; however, the number of birds in each groups was not equal (modified from Campbell et al., 2016). This method allowed us to overcome the issue where some birds could have the same frequency of outdoor uses, but be divided into various ranging profiles, if the ranging profiles would be created based on equal bird numbers.

The dataset with the assigned ranging profile group was matched with the welfare assessment outcomes for each individual bird. Statistical analyses were performed with SAS (version 9.4). The GLIMMIX procedure was used to perform general linear mixed models for the normally distributed data on the body weight and generalized linear mixed models, with binomial distribution

Table 2. Description of the welfare indicators derived from Welfare Quality–Poultry Protocol (Butterworth et al., 2009).

Welfare indicator	Score	Description
Plumage condition	0	No or slight wear (nearly), complete feathering
	1	Moderate wear, that is damaged feathers (worn, deformed) or one or more featherless areas <5 cm in diameter
	2	At least one featherless area ⩾5 cm in diameter
Comb pecking wounds	0	No evidence of pecking wounds
	1	Less than 3 pecking wounds
	2	Starting from 3 pecking wounds and more
Skin injuries	0	No lesions, only single (<3) pecks (punctiform damage <0.5 cm diameter) or scratches
	1	At least one lesion <2 cm diameter at largest extent or ≥3 pecks or scratches
	2	At least one lesion ≥2 cm diameter at largest extent
Dirtiness	0	No signs of dirtiness
	1	20% or less of the body area dirty
	2	More than 20% of body area dirty
Toe damage	0	No toe damage
	1	Wounds on one toe or missing (parts of) one toe
	2	Wounds on one or more toes and/or missing (parts of) one or more toes
Walking difficulty	0	Normal, dextrous, and agile
	1	Slight abnormality, but difficult to define Definite and identifiable abnormality
	2	Obvious abnormality, affects ability to move Severe abnormality, only takes a few steps Incapable of walking
Hock burn	0	No evidence of hock burn (score '0')
	1	Minimal evidence of hock burn (scores '1' and '2')
	2	Evidence of hock burn (scores '3' and '4')
Footpad dermatitis	0	No lesion, slight discoloration of the skin, or healed lesion
	1	Mild lesion, superficial discoloration of the skin, and hyperkeratosis
	2	Severe lesion, epidermis is affected, blood scabs, hemorrhage, and severe swelling of the skin
Eye pathologies	0	No eye pathologies
	1	Swelling of the eyelids and the skin around the eyes
	2	Closure of the eye/eyes and discharge from the eyes
Diarrhea	0	No signs of diarrhea
	1	Altered fecal state—discolored feces or increased liquid content
Respiratory infections	0	No signs of respiratory infections
	1	Increased or labored respiratory effort, sneezing, and/or associated with audible breathing sounds

and logit link, on the data on welfare indicators, applying breed and ranging profile group as fixed effects and including their interaction in both models. The assumptions of homogeneity of variance and normally distributed residuals were examined visually using the conditional studentized residuals plots. Pen was included in the model as a random effect. Results are shown as means with corresponding standard errors, and P-values below 0.05 were considered significant. Tukey's post hoc test was performed to investigate significant differences between test groups. Chi-square tests, calculated using the PROC FREQ script with the "chisq" option in SAS (version 9.4), were used to test the associations between all the welfare indicators, transformed into binary data, separately for Green-legged Partridges and Sasso birds. The associations were expressed by the Cramer's V coefficient, which is a chi square–based measure of association, equal to the Phi coefficient in the case of a 2×2 contingency tables, with a minimum dimension of -1 and maximum of 1. If expected cell count was less than 5, chi-square test may not be a valid test. Instead, Fisher's exact test two-sided probability (P-value) was applied.

RESULTS

Associations Between Ranging Profiles, Breed, and the Welfare Indicators

Body weight was the only parameter significantly influenced by the interaction between breed and ranging profile (Figure 2), while there was a strong tendency for an effect of this interaction on the respiratory infections (Figure 3). All three ranging profiles of the Sasso birds differed significantly regarding body weight ($P < 0.0001$), where the highest body weight was found in the outdoor-preferring birds, and the lowest in the indoor-preferring birds, with the moderate-outdoor group being intermediate. Such significant differences were not identified between ranging profiles of Green-legged Partridges. Furthermore, within all ranging profiles, the body weight of Sasso was significantly

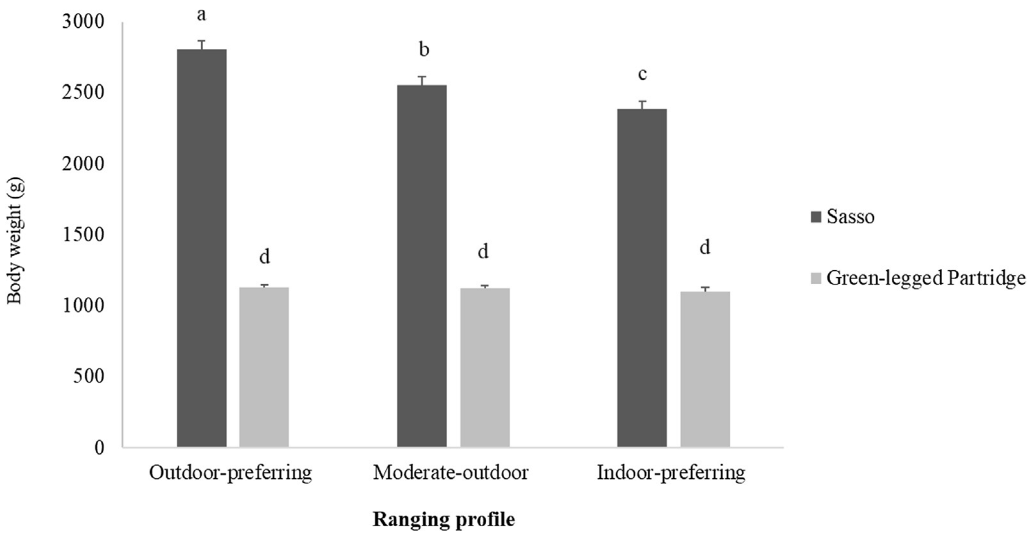

Figure 2. Effect of the interaction between ranging profile and the breed on body weight expressed in grams. The significance of the effect of the presented interaction is: F(2,30) = 8.69; $P = 0.0002$. Different letters (a, b, c, and d) indicate statistically significant differences ($P < 0.05$).

higher as compared to Green-legged Partridges ($P < 0.0001$; Figure 2).

A strong tendency for higher occurrence of respiratory infection was observed in Sasso birds from each ranging profile, as compared to matching ranging profiles presented by Green-legged Partridges (outdoor-preferring: $P = 0.0012$; moderate-outdoor: $P < 0.0001$; and indoor-preferring: $P = 0.0247$; Figure 3). Indoor-preferring Green-legged Partridges tended to present more respiratory infections, as compared to the 2 other ranging profiles within the breed (outdoor-preferring: $P = 0.0291$; moderate-outdoor: $P = 0.0448$; Figure 3). No differences were found in the presence of respiratory infections between ranging profiles of the Sasso birds.

Significantly lower welfare status of the Sasso, as compared to Green-legged Partridges birds, was observed for plumage condition, comb pecking wounds, FPD, dirtiness, and toe damage (Table 3).

Toe damage was the only welfare indicator affected by the ranging profile ($P = 0.017$; Table 4). There was a tendency for indoor-preferring birds to present more toe damage, as compared to moderate-outdoor birds ($P = 0.053$) and outdoor-preferring birds ($P = 0.0114$), as presented in the Table 4.

Associations were identified among welfare indicators for Green-legged Partridges and for Sasso birds (Table 5). Among Green-legged Partridges, plumage condition score was positively associated with the comb pecking wounds.

For Sasso birds, positive associations were identified for plumage condition with dirtiness and diarrhea. Dirtiness in those birds was positively associated with the

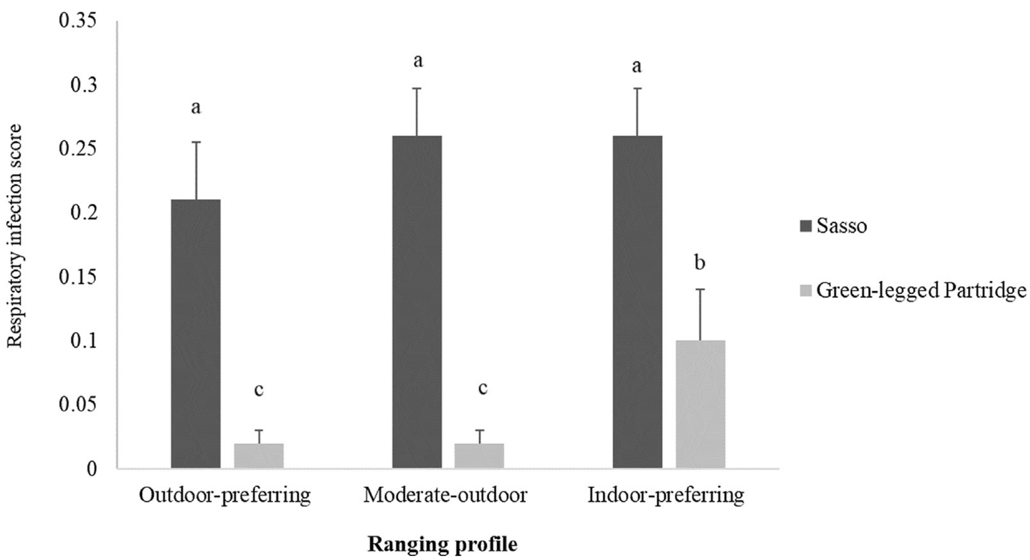

Figure 3. Effect of the interaction between ranging profile and the breed on respiratory infection score. The tendency for the significant effect of the presented interaction is: $F_{(2,30)} = 3.28$; $P = 0.0513$. Different letters (a, b, and c) indicate statistically significant differences ($P < 0.05$).

Table 3. Occurrence of the welfare indicators within the 2 breeds, presented as a mean ± SEM and its associated test statistics.

Welfare indicator	Sasso	Green-legged Partridge	Num DF	Den DF	F Value	*P* Value
Plumage condition	0.42 ± 0.03[a]	0.07 ± 0.02[b]	1	30	71.5	<0.0001
Comb pecking wounds	0.43 ± 0.03[a]	0.06 ± 0.02[b]	1	30	60.08	<0.0001
Skin injuries	0.03 ± 0.01	0 ± 0	1	30	0.00	0.970
FPD	0.27 ± 0.03[a]	0.1 ± 0.02[b]	1	30	21.21	<0.0001
Hock burn	0.07 ± 0.02	0 ± 0	1	30	0.00	0.968
Dirtiness	0.37 ± 0.03[a]	0 ± 0.01[b]	1	30	52.23	<0.0001
Toe damage	0.1 ± 0.02[a]	0.02 ± 0.01[b]	1	30	11.44	0.002
Eye pathologies	0.00 ± 0.01	0.06 ± 0.02	1	30	0.00	0.971
Respiratory infections	0.26 ± 0.03	0.04 ± 0.01	1	30	38.20	<0.0001
Diarrhea	0.15 ± 0.02	0.00 ± 0.001	1	30	0.00	0.970
Walking difficulty	0.07 ± 0.02	0.00 ± 0.03	1	30	0.00	0.966
Body weight	2733.3 ± 98.4[a]	1124.2 ± 30.6[b]	1	30	502.13	<0.0001

Abbreviations: Den DF, denominator degree of freedom; Num DF, numerator degree of freedom.

presence of diarrhea. Moreover, in Sasso, walking difficulty was positively associated with toe damage and comb pecking wounds.

DISCUSSION

The outdoor range provided in commercial poultry farms is usually exposed to highly variable environmental conditions (i.e., sun, rain, snow, wind, storms), as compared to climate-controlled indoor housing (Richards et al., 2011; Gilani et al., 2014), provides no or little shelter, and may pose increased risk of predation (Pettersson et al., 2016; Bestman and Bikker-Ouwejan, 2020). Thus, individuals or breeds, even those better suited to organic production regarding growth rates, that are less able to cope with stress may be fearful of entering the outdoor range (Campbell et al., 2016; Lindholm et al., 2016). To convince free-range broiler producers to implement strategies encouraging their chickens to use the outdoor area, more, clear evidence is needed, proving that outdoor-preferring birds present better or at least equal welfare as compared to indoor-preferring and moderate-outgoing birds.

Differences in coping style have been identified between more reactive indoor-preferring laying hens, as compared to proactive outdoor-preferring and moderate-outdoor hens (Campbell et al., 2016). Because coping styles are strongly associated with the levels of stress vulnerability, including the individual vulnerability to disease (Koolhaas and Van Reenen, 2016), we suspected that welfare condition of birds presenting different ranging profile may also vary. This approach has not previously been undertaken for meat chicken breeds. Furthermore, existing knowledge, indicating that venturing outdoors may provide some welfare benefits to domestic poultry (Bestman and Wagenaar, 2003; Rodriguez-Aurrekoetxea and Estevez, 2016), has mainly been obtained from studies designed to compare the welfare of birds provided free-range access to birds reared only indoors.

Within all ranging profiles, the body weight of Sasso was significantly higher as compared to Green-legged Partridges. In the present study, the 2 breeds were matched by age. Another approach could be to match birds by developmental phase or body weight at slaughter, where the welfare is potentially most compromised (Christensen et al. 2003). Green-legged Partridges reach slaughter weight at ±5 mo of age, while for Sasso, it is the age of 11 wk, at which the current experiment terminated. Extending the rearing period of Green-legged Partridges to 5 mo, allowing them to reach slaughter age, would cause encountering of different seasonal and weather effects for both breeds, known to influence birds' use of the free-range areas (Nielsen et al., 2003).

Among Sasso birds, the highest body weight was recorded in outdoor-preferring birds, lower in moderate-outdoor group, and the lowest in indoor-

Table 4. Occurrence of the welfare indicators within the different ranging profiles, presented as mean ± SEM and its associated test statistics.

Welfare indicator	Outdoor-preferring	Moderate-outdoor	Indoor-preferring	Num DF	Den DF	F Value	*P* Value
Plumage condition	0.17 ± 0.03	0.21 ± 0.03	0.21 ± 0.04	2	30	0.41	0.668
Comb pecking wounds	0.21 ± 0.04	0.22 ± 0.03	0.13 ± 0.04	2	30	1.36	0.272
Skin injuries	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	2	30	0.00	0.999
FPD	0.12 ± 0.02	0.21 ± 0.03	0.19 ± 0.04	2	30	2.48	0.101
Hock burn	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	2	30	0.00	0.999
Dirtiness	0.06 ± 0.03	0.09 ± 0.03	0.14 ± 0.04	2	30	1.05	0.361
Toe damage	0.02 ± 0.01[b]	0.03 ± 0.02[b]	0.1 ± 0.03[a]	2	30	4.68	0.017
Eye pathologies	0.04 ± 0.01	0.09 ± 0.02	0.04 ± 0.01	2	30	2.38	0.110
Respiratory infections	0.06 ± 0.02	0.09 ± 0.03	0.17 ± 0.03	2	30	3.33	0.0495
Diarrhea	0.00 ± 0.02	0.00 ± 0.022	0.05 ± 0.02	2	30	0.00	1.000
Walking difficulty	0.02 ± 0.01	0.00 ± 0.01	0.06 ± 0.02	2	30	1.31	0.284
Body weight	1817.6 ± 64.4[b]	1672.8 ± 57.3[c]	1972.2 ± 59.8[a]	2	30	15.70	<0.0001

Abbreviations: Den DF, denominator degree of freedom; Num DF, numerator degree of freedom.

Table 5. Associations between different welfare indicators in Green-legged Partridges (top) and Sasso (bottom) birds presented as the Cramer's V coefficient and its associated P value in brackets.

Welfare indicator	Breed	Plumage condition	Comb pecking wounds	Skin injuries	FPD	Hock burn	Dirtiness	Toe damage	Eye pathologies	Respiratory infections	Diarrhea
Comb pecking wounds	Green-legged Partridge	**0.4439 (0.0010)**									
Skin injuries		[1]	[1]								
FPD		[1]	[1]	[1]							
Hock burn		[1]	[1]	[1]	[1]						
Dirtiness		[1]	[1]	[1]	[1]	[1]					
Toe damage		[1]	[1]	[1]	[1]	[1]	[1]				
Eye pathologies		[1]	[1]	[1]	[1]	[1]	[1]	[1]			
Respiratory infections		−0.0859 (0.5240)	−0.0544 (0.6866)	[1]	[1]	[1]	[1]	[1]	[1]		
Diarrhea		[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]	
Walking difficulty		−0.0602 (0.6553)	−0.0381 (0.7775)	[1]	[1]	[1]	[1]	[1]	[1]	[1]	[1]
Comb pecking wounds	Sasso	0.1407 (0.3246)									
Skin injuries		0.1504 (0.2926)	0.0212 (0.8822)								
FPD		0.1052 (0.4615)	0.1599 (0.2630)	−0.0298 (0.8349)							
Hock burn		[1]	[1]	[1]	[1]						
Dirtiness		**0.3153 (0.0273)**	0.0161 (0.9104)	−0.0763 (0.5932)	0.1005 (0.4817)	[1]					
Toe damage		−0.1980 (0.1657)	0.1599 (0.2630)	−0.0298 (0.8349)	−0.0208 (0.8841)	[1]	−0.2073 (0.1468)				
Eye pathologies		[1]	−0.1303 (0.3618)	−0.0298 (0.8349)	−0.0208 (0.8841)	[1]	0.1005 (0.4817)	−0.0208 (0.8841)			
Respiratory infections		−0.0359 (0.8015)	0.2079 (0.1455)	0.0475 (0.7394)	−0.1149 (0.4214)	[1]	−0.0711 (0.6187)	0.1814 (0.2042)	−0.1149 (0.4214)		
Diarrhea		**0.3220 (0.0242)**	−0.0657 (0.6456)	−0.0911 (0.5236)	−0.0638 (0.6554)	[1]	**0.3076 (0.0313)**	−0.0638 (0.6554)	−0.0638 (0.6554)	−0.0116 (0.9355)	
Walking difficulty		0.1563 (0.2739)	**0.2556 (0.0436)**	−0.1045 (0.4647)	−0.0731 (0.6089)	[1]	0.2446 (0.0868)	**0.2850 (0.0460)**	−0.0731 (0.6089)	0.1167 (0.4142)	0.1873 (0.1898)

If the P value is < 0.05, the Cramer's V and P value are indicated by the bold font. If expected cell count was less than 5, chi-square test may not be a valid test. Fisher's exact test two-sided probability (P) was provided.

[1]If there were rows and/or columns, indicating either 0 or 1 category in the frequency table missing, value was not provided.

preferring birds. This is in contrast to studies indicating that outdoor access (more frequent and further away from the shed) caused a reduction in body weight of broilers (Połtowicz and Doktor, 2011; Taylor et al., 2020). Lower body weight may imply that birds have trouble accessing feed and water due to, for example, walking difficulties, disease, or other welfare issues (Weeks et al., 2000; Butterworth et al., 2002; Knowles et al., 2008; Vasdal et al., 2019). For instance, broilers have been found to decrease feed intake with increasing FPD (Martland, 1985). We therefore suspect that lighter Sasso birds were potentially affected by some welfare issues requiring further investigation.

We observed a tendency of an effect of the breed by ranging profile interaction on respiratory infections. Indoor-preferring Green-legged Partridges were scored much higher regarding respiratory infections, as compared to the 2 other ranging profiles. It is possible that more frequent use of outdoor ranges has a beneficial effect on the respiratory tract condition. Birds spending more time indoors are longer exposed to climatic conditions in the house, and therefore, the risk of respiratory infection may be related to the poor indoor environment. Poor litter quality may impair excreta absorption and promote the proliferation of bacteria and fungi, as well as increasing gas emissions (Berg, 2004). Exposure to high ammonia levels (>10 ppm) is known to increase birds sensitivity to dust, while dust may irritate the respiratory tract, causing bronchitis (David et al., 2015). In case of moderate-outdoor and outdoor-preferring Green-legged Partridges, their more frequent outdoor use is likely to minimize problems caused by dust and poor litter quality (Sans et al., 2014). Sasso birds representing each of the ranging profiles were characterized by a higher occurrence of respiratory infections as compared to matching ranging profile of Green-legged Partridges. It has previously been shown that the litter quality is significantly worse when housing faster growing broilers (ROSS 208), as compared to slower growing broilers (Labresse), both provided with outdoor access (Christensen et al. 2003). The faster growth rate in Sasso birds compared to Green-legged Partridges could have resulted in potentially worse litter quality in the pens housing Sasso. Furthermore, we suspect that Sasso birds due to the relatively smaller size of respiratory organs, compared to their body size and genetically programmed higher metabolic turnover, may be more sensitive to respiratory infections than Green-legged Partridges.

Significant effect of breed was identified for FPD, plumage condition, comb pecking wounds, dirtiness, and toe damage. Footpad dermatitis is considered a painful condition, which is associated with health and performance problems (Ask, 2010). It reduces the birds' ability of reaching the outdoor area (Granquist et al., 2019). Sasso birds presented higher scores of FPD, as compared to Green-legged Partridges. The FPD risk factor may relate to the indoor environment, namely contact with litter of poor quality causing bacteriological contamination (Sarica et al., 2014). Another risk factor for FPD is the quality of the outdoor area, where presence of stones or high humidity may damage the skin, which may subsequently be infected with bacteria (Sans et al., 2014). Furthermore, estimates of the heritability of FPD are known to be moderate, between 20 and 30% (EFSA, 2010). Higher susceptibility to FPD could therefore have a genetic background, where selection for meat production could decrease the skin resistance to outdoor conditions.

Sasso birds presented significantly more damaged plumage, as compared to Green-legged Partridges. In poultry production, there is often concern about the quantity and/or quality of feathering. The concerns include the adequacy of protective feather cover (Leeson and Walsh, 2004). In free-ranging systems, individuals may choose to spend less time on the range if plumage cover is reduced, as their thermoregulation may be impaired (Leeson and Walsh, 2004). Feathering can be influenced by environmental or nutritional status of a bird (Leeson and Walsh, 2004). Rate of feathering is also influenced by genetics, since for decades broilers have been selected for slower versus fast feathering, to allow for easier sexing of the day-old chicks (Leeson and Walsh, 2004). Nutritional and environmental conditions in the present study were equal for both breeds. Therefore, we may suspect that the higher level of genetic selection of Sasso, including potential remaining of the slow feathering breeding objective, as compared to heritage Green-legged Partridge, could explain better plumage condition in the latter.

Comb pecking wounds were more often present in Sasso birds as compared to Green-legged Partridges. Aggressive pecking is aimed at the head of the subordinate and can cause severe damage to the comb (Buitenhuis et al., 2009). Both endogenous (genetic and physiological) and environmental (feeding, density, and housing conditions) factors seem to influence aggression (as reviewed by Wysocki et al., 2010). In Sasso, comb pecking wounds were in the present study positively associated with walking difficulty, which may suggest that comb pecks are directed toward weaker individuals, not only socially but also physically. Better comb condition was recently found in laying hens provided with the free-ranging area (Bari et al., 2020). We suspect that comb pecks observed in Sasso birds could also have a genetic background, while our study did not confirm that frequency of outdoor use may be beneficial.

More Sasso birds were found to have dirty plumage than Green-legged Partridge birds. Dirty feathers have been suggested in broilers as an iceberg indicator, which provides an overall assessment of welfare (EFSA, 2010). A dirty environment could increase risk of infection in the birds (Reyna et al., 1983). Dirtiness can also be associated with gastrointestinal issues (Souillard et al., 2019). In the present study, in Sasso, there was a positive association of dirtiness with presence of diarrhea. Analysis of data collected in the current experiment regarding gut health may provide more explanation on the identified differences in levels of dirtiness. Dirtiness may also occur in birds which spend larger proportions of their time in the litter, either because they are heavier birds, such as Sasso (Yngvesson et al., 2017), who perch less frequently or in weak birds who are unable to get up due to various types of weakness (Marchewka et al., 2013). In this study, dirtiness in Sasso birds was positively associated with the plumage condition. Feather pecking, damaging the feather cover of a victim bird, is believed to be redirected ground pecking in relation to foraging behavior (e.g., Huber-Eicher and Wechsler, 1997). Dirtier birds in the present study may become more attractive for others to peck, due to litter pieces, sand, or dust present on their feathers. Increased dirtiness of the Sasso birds could indicate as well that their health was more challenged, as compared to Green-legged Partridges, confirmed by current results regarding some welfare indicators. Further investigation would also be beneficial regarding use of dirtiness, as an on-farm “iceberg indicator” in free-range systems, as it was described for conventional systems (Jacobs et al., 2016).

We found that Sasso birds showed higher prevalence of toe damage scores, as compared to Green-legged Partridges. We have also identified a significant positive association between toe damage and walking difficulties. Walking difficulties in broilers with poor gait scores has been extensively studied (Weary et al., 2006; Naas et al., 2009). Rapid growth rate is the main cause of locomotion problems (Bessei, 2006) with the frequency of leg disorders increasing proportionally to body weight (Baracho et al., 2012). However, continuous exercise has been shown to contribute to increased bone strength in poultry (Bizeray et al., 2000). We confirmed the positive relation between use of the outdoor range and mobility identified previously (Taylor et al., 2020), as in present study outdoor-preferring and moderate-outgoing birds were characterized by the lower scores for walking difficulties, while overall scores of this welfare indicator were low.

Relations of toe damage and asymmetry with walking difficulties, reduced mobility, and reduced possibility to access resources exist (Baracho et al., 2012). Although use of slower-growing broilers such as Sasso, as an alternative to fast growing hybrids, has shown to be more efficient in reducing many welfare issues, like leg weakness (Bessei, 2006), heritage breeds of poultry like Green-legged Partridge seem to withstand production under organic conditions better regarding leg health.

Some welfare issues, like hock burns or skin injuries, present at a low extent in Sasso, were not observed in Green-legged Partridges at all. High body weight of broilers is a known risk factor for the occurrence of hock burns (Louton et al., 2020). In addition to the plumage, injurious pecking may also be directed toward the skin (Riber and Hinrichsen, 2017). In the present study, the skin injuries presence was very low, despite that birds were non-beak trimmed. We found no effect of the ranging profile on whether or not the birds had plumage damage caused by injurious pecking.

In conclusion, we found clear associations between ranging profiles and welfare of meat-purpose chickens regarding respiratory infections, as well as for body weight. Regardless of the breed, toe damages were more frequent in indoor-preferring birds, as compared to moderate-outdoor and outdoor-preferring ranging profiles. There is a need for further research to establish the causal relationship between range use and indicators of birds' welfare. It remains unknown whether the use of outdoor areas prevents development of welfare issues or if birds with a suboptimal welfare condition become indoor-preferring individuals.

ACKNOWLEDGMENTS

This work was funded within the project entitled: Optimising the use of the free range as the key to improve organic chicken production; Acronym: “Free-Birds” 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. The authors would like to thank The National Centre for Research and Development for help in managing and executing this project under agreement no. COREORG/COFUND/FREE-BIRDS/2/2018. The authors would also like to thank technicians, students, and animal caretakers for their work during the project.

Conflict of Interest Statement: The authors did not provide a conflict of interest statement.

REFERENCES

ACMF. 2011. The Australian Chicken Meat Industry: An Industry in Profile. Australian Chicken Meat Federation (ACMF) Inc., North Sydney, NSW.

AECL. 2012. Australian Egg Corporation Limited Annual Report 2012. Australian Egg Corporation, North Sydney, NSW.

Ask, B. 2010. Genetic variation of contact dermatitis in broilers. Poult. Sci. 89:866–875.

Baracho, M. S., I. A. Nääs, L. G. F. Bueno, G. R. Nascimento, and D. J. Moura. 2012. Broiler walking ability and toe asymmetry under harsh rearing conditions. Rev. Bras. Cienc. Avic. 14:217–222.

Bari, M. S., Y. C. S. M. Laurenson, A. M. Cohen-Barnhouse, S. W. Walkden-Brown, and D. L. M. Campbell. 2020. Effects of outdoor ranging on external and internal health parameters for hens from different rearing enrichments. Peer J. 8:e8720.

Berg, C. 2004. Pododermatitis and hock burn in broiler chickens. Pages 37–49 in Measuring and Auditing Broiler Welfare. J. Linden, ed. CABI Publishing, Wallingford, UK.

Bergmann, S., A. Schwarzer, K. Wilutzky, H. Louton, J. Bachmeier, P. Schmidt, M. Erhard, and E. Rauch. 2017. Behavior as welfare indicator for the rearing of broilers in an enriched husbandry environment—a field study. J. Vet. Behav. Clin. Appl. Res. 19:90–101.

Bessei, W. 2006. Welfare of broilers: a review. Worlds Poult. Sci. J. 62:455–466.

Bestman, M. W. P., and J. P. Wagenaar. 2003. Farm level factors associated with feather pecking in organic laying hens. Livest. Prod. Sci. 80:133–140.

Bestman, M., and J. Bikker-Ouwejan. 2020. Predation in organic and free-range egg production. Animals 10:177.

Bizeray, D., C. Leterrier, P. Constantin, M. Picard, and J. Faure. 2000. Early locomotor behaviour in genetic stocks of chickens with different growth rates. Appl. Anim. Behav. Sci. 68:231–242.

Buitenhuis, B., J. Hedegaard, L. Janss, and P. Sørensen. 2009. Differentially expressed genes for aggressive pecking behaviour in laying hens. BMC Genomics 10:1–10.

Butterworth, A., C. Arnould, T. G. C. M. M van Niekerk, I. Veissier, L. Keeling, G. van Overbeke, and V. Bedaux. 2009. Welfare Quality R Assessment Protocol for Poultry. 1st ed. Pages 60–81 in Welfare Quality R Consortium, Lelystad, the Netherlands.

Butterworth, A., C. Weeks, P. R. Crea, and S. C. Kestin. 2002. Dehydration and lameness in a broiler flock. Anim. Welf. 11:89–94.

Campbell, D. L. M., G. N. Hinch, J. A. Downing, and C. Lee. 2016. Fear and coping styles of outdoor-preferring, moderate-outdoor and indoor-preferring free-range laying hens. Appl. Anim. Behav. Sci. 185:73–77.

Christensen, J. W., B. L. Nielsen, J. F. Young, and F. Nøddegaard. 2003. Effects of calcium deficiency in broilers on the use of outdoor areas, foraging activity and production parameters. Appl. Anim. Behav. Sci. 83:229–240.

da Silva, D. C. F., A. M. V. de Arruda, and A. A. Gonçalves. 2017. Quality characteristics of broiler chicken meat from free-range and industrial poultry system for the consumers. J. Food Sci. Technol. 54:1818–1826.

David, B., C. Mejdell, V. Michel, V. Lund, and R. O. Moe. 2015. Air quality in alternative housing systems may have an impact on laying hen welfare. Part II-ammonia. Animals 5:886–896.

Dawkins, M. S. 2003. Behaviour as a tool in the assessment of animal welfare. Zool. Jena Ger. 106:383–387.

de Jonge, J., and H. C. M. van Trijp. 2013. The impact of broiler production system practices on consumer perceptions of animal welfare. Poult. Sci. 92:3080–3095.

Durali, T., P. Groves, and A. J. Cowieson. 2012. Comparison of performance of commercial conventional and free-range broilers. Pages 19–22 in 23rd Annual Australian Poultry Science Symposium. Sydney, Australia.

Erian, I., and C. J. C. Phillips. 2017. Public understanding and attitudes towards meat chicken production and relations to consumption. Animals 7:20.

EU. 2007. Council Directive 834/2007 on organic production and labelling of organic products. Off. J. Eur. Communities L. 189:1–23.

EU. 2008. Commission regulation (EC) no 889/2008 of 5 September 2008 laying down detailed rules for the implementation of council regulation (EC) no 834/2007 on organic production and labelling of organic products with regard to organic production, labelling and co. Off. J. Eur. Union L. 250:1–84.

Getiso, A., B. Bangu, B. Zeleke, G. Desta, T. Abiti, E. Abrham, and H. Jemal. 2017. Production performance of Sasso (distributed by ethio-chicken private poultry farms) and Bovans brown chickens breed under village production system in three agro-ecologies of Southern Nations, Nationalities, and Peoples Regional State (SNNPR), Ethiopia. Int. J. Livest. Prod. 8:145–157.

Gilani, A. M., T. G. Knowles, and C. J. Nicol. 2014. Factors affecting ranging behaviour in young and adult laying hens. Br. Poult. Sci. 55:127–135.

Granquist, E. G., G. Vasdal, I. C. De Jong, and R. O. Moe. 2019. Lameness and its relationship with health and production measures in broiler chickens. Animal 13:2365–2372.

Hartcher, K., and H. Lum. 2020. Genetic selection of broilers and welfare consequences: a review. World's Poult. Sci. J. 14:154–167.

Huber-Eicher, B., and B. Wechsler. 1997. Feather pecking in domestic: its relation to dustbathing and foraging. Anim. Behav. 54:757–768.

Jacobs, L., E. Delezie, L. Duchateau, K. Goethals, and F. Tuyttens. 2016. Broiler chickens dead on arrival: associated risk factors and welfare indicators. Poult. Sci. 96:259–265.

Kestin, S. C., T. G. Knowles, A. E. Tinch, and N. G. Gregory. 1992. Prevalence of leg weakness in broiler chickens and its relationship with genotype. Vet. Rec. 131:190–194.

Knowles, T. G., S. C. Kestin, S. M. Haslam, S. N. Brown, L. E. Green, A. Butterworth, S. J. Pope, D. Pfeiffer, and C. J. Nicol. 2008. Leg disorders in broiler chickens: prevalence, risk factors and prevention. PLoS One 3:e1545.

Koolhaas, J. M., and C. G. Van Reenen. 2016. Animal Behavior and Well-Being Symposium: interaction between coping style/personality, stress, and welfare: Relevance for domestic farm animals1. J. Anim. Sci. 94:2284–2296.

Krawczyk, J. 2009. Quality of eggs from Polish native Greenleg Partridge chicken-hens maintained in organic vs. backyard production systems. Anim. Sci. Pap. Rep. 27:227–236.

Leeson, S., and T. Walsh. 2004. Feathering in commercial poultry I. Feather growth and composition. Worlds Poult. Sci. J. 60:42–51.

Lindholm, C., L. Karlsson, A. Johansson, and J. Altimiras. 2016. Higher fear of predators does not decrease outdoor range use in free-range Rowan Ranger broiler chickens. Acta Agr. Scand. A.-An. 66:231–238.

Louton, H., A. Piller, S. Bergmann, M. Erhard, J. Stracke, B. Spindler, N. Kemper, P. Schmidt, B. Schade, B. Boehm, E. Kappe, J. Bachmeier, and A. Schwarzer. 2020. Histologically validated scoring system for the assessment of hock burn in broilers. Avian Pathol. 49:230–242.

Marchewka, J., T. T. N. Watanabe, V. Ferrante, and I. Estévez. 2013. Welfare assessment in broiler farms: Transect walks versus individual scoring. Poult. Sci. 92:2588–2599.

Martland, M. F. 1985. Ulcerative dermatitis in broiler chickens: the effects of wet litter. Avian Pathol. 14:353–364.

Naas, I. a., I. C. L. a. Paz, M. S. Baracho, a. G. Menezes, L. G. F. Bueno, I. C. L. Almeida, and D. J. Moura. 2009. Impact of lameness on broiler well-being. J. Appl. Poult. Res. 18:432–439.

Nielsen, B. L., M. G. Thomsen, P. Sørensen, and J. F. Young. 2003. Feed and strain effects on the use of outdoor areas by broilers. Br. Poult. Sci. 44:161–169.

EFSA. 2010. Scientific Opinion on the influence of genetic parameters on the welfare and the resistance to stress of commercial broilers. EFSA J. 8:1–82.

Pettersson, I. C., R. Freire, and C. J. Nicol. 2016. Factors affecting ranging behaviour in commercial free-range hens. Worlds. Poult. Sci. J. 72:137–150.

Połtowicz, K., and J. Doktor. 2011. Effect of free-range raising on performance, carcass attributes and meat quality of broiler chickens. Anim. Sci. Pap. Rep. 29:139–149.

Reyna, P. S., L. R. McDougald, and G. F. Mathis. 1983. Survival of coccidia in poultry litter and reservoirs of infection. Avian Dis. 27:464–473.

Riber, A. B., and L. K. Hinrichsen. 2017. Welfare consequences of omitting beak trimming in barn layers. Front. Vet. Sci. 4:1–9.

Riber, A. B., H. A. Van De Weerd, I. C. De Jong, and S. Steenfeldt. 2018. Review of environmental enrichment for broiler chickens. Poult. Sci. 97:378–396.

Richards, G. J., L. J. Wilkins, T. G. Knowles, F. Booth, M. J. Toscano, C. J. Nicol, and S. N. Brown. 2011. Continuous monitoring of pop hole usage by commercially housed free-range hens throughout the production cycle. Vet. Rec. 169:338.

Rodriguez-Aurrekoetxea, A., and I. Estevez. 2016. Use of space and its impact on the welfare of laying hens in a commercial free-range system. Poult. Sci. 95:2503–2513.

Sanchez, C., and I. Estevez. 1998. The Chickitizer Software Program. University of Maryland, College Park, MD.

Sans, E. C. O., J. F. Federici, F. Dahlke, and C. F. M. Molento. 2014. Evaluation of free-range broilers using the welfare quality® protocol. Rev. Bras. Cienc. Avic. 16:297–306.

Sarica, M., U. S. Yamak, and M. A. Boz. 2014. Einfluss des produktionssystems auf das vorkommen von Fußballen-Dermatiden (FPD) bei langsam, mittelschnell und schnell wachsenden broilern. Eur. Poult. Sci. 78:1–10.

Siwek, M., D. Wragg, A. Sławińska, M. Malek, O. Hanotte, and J. M. Mwacharo. 2013. Insights into the genetic history of Green-legged Partridgelike fowl: MtDNA and genome-wide SNP analysis. Anim. Genet. 44:522–532.

Souillard, R., J. M. Répérant, C. Experton, A. Huneau-Salaun, J. Coton, L. Balaine, and S. Le Bouquin. 2019. Husbandry practices, health, and welfare status of organic broilers in France. Animals 9:1–12.

Taylor, P. S., P. H. Hemsworth, P. J. Groves, S. G. Gebhardt-Henrich, and J. L. Rault. 2017. Ranging behaviour of commercial free-range broiler chickens 1: factors related to flock variability. Animals 7:54.

Taylor, P. S., P. H. Hemsworth, P. J. Groves, S. G. Gebhardt-Henrich, and J. L. Rault. 2018. Ranging behavior relates to welfare indicators pre- and post-range access in commercial free-range broilers. Poult. Sci. 97:1861–1871.

Taylor, P. S., P. H. Hemsworth, P. J. Groves, S. G. Gebhardt-Henrich, and J. L. Rault. 2020. Frequent range visits further from the shed relate positively to free-range broiler chicken welfare. Animal 14:138–149.

Vasdal, G., E. G. Granquist, E. Skjerve, I. C. De Jong, C. Berg, V. Michel, and R. O. Moe. 2019. Associations between carcass weight uniformity and production measures on farm and at slaughter in commercial broiler flocks. Poult. Sci. 98:4261–4268.

Weary, D. M., L. Niel, F. C. Flower, D. Fraser, D. M. Weary, L. Niel, F. C. Flower, and D. Fraser. 2006. Identifying and preventing pain in animals identifying and preventing pain in animals. Appl. Anim. Behav. Sci. 100:64–76.

Weeks, C., T. Danbury, H. Davies, P. Hunt, and S. Kestin. 2000. The behaviour of broiler chickens and its modification by lameness. Appl. Anim. Behav. Sci. 67:111–125.

Wysocki, M., W. Bessei, J. Kjaer, and J. Bennewitz. 2010. Genetic and physiological factors influencing feather pecking in chickens. World Poult. Sci. J. 66:659–672.

Yngvesson, J., M. Wedin, S. Gunnarsson, L. Jönsson, H. Blokhuis, and A. Wallenbeck. 2017. Let me sleep! Welfare of broilers (*Gallus gallus domesticus*) with disrupted resting behaviour. Acta Agr. Scand. A.-An. 67:123–133.