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Behavioural indicators of range use in four broiler strains

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ABSTRACT

Free-range systems provide an outdoor range for broilers to give them the possibility to express a higher frequency and a wider range of behaviours, such as exploration, compared with those raised indoors. Greater variability in outdoor range use between individuals of the same flock is often reported. Individual variation in range use may result from differences in early-life behaviour or genetic background. Understanding how early-life behaviour influences range use may provide opportunities to enhance and predict range use. Previous studies have shown that range use could be influenced by the animal's personality traits such as social motivation, boldness and foraging motivation. Therefore, this study investigated personality traits in several broiler strains, namely Hubbard JA757, Hubbard S757N, White Bresse and a dual-purpose strain; we examined the latter as it represents a potential solution to the ban of 1-day-old chick culling. The present study also investigated early-life behaviours, before range access, of range use to identify and assess the stability of these early-life indicators among the four broiler strains. For that purpose, we recorded the behaviour and range use of 100 male chickens per strain, both in the barn and during individual tests, before and after range access. We examined which behaviours were time consistent, whether early-life behaviours were influenced by genetic variation and whether early-life behavioural indicators predicted range use regardless of genetic variation. There was a significant ($p < 0.001$) difference between strains in several early-life behaviours, including the time spent resting or standing. Range use was time consistent regardless of the strain as our range use indicator followed a high-quality linear regression model ($R^2 > 0.7$) for 82–99% of the individuals depending on their strain. Besides, time consistency of social motivation and boldness seemed to depend on the strain. Even though foraging showed low ($\rho = 0.2$ – 0.4) positive correlations with range use in three of the four studied strains, there were no significant and strong correlations in the four studied strains between early-life behavioural indicators and range use. In conclusion, our results show that the link between chick behaviour (before range access) and range use can be modulated by the bird's strain. It is crucial to consider all these different factors to better understand how range use varies within and between flocks.

1. Introduction

Meat consumption of free-range livestock has increased during the last decades (FiBL and IFOAM, 2021), driven by the consumer's belief

that free range and animal welfare are bound together (Pinto da Rosa et al., 2021). By providing an outdoor range for broilers, free-range systems theoretically give to broilers the possibility to express more behaviours, such as exploration, than indoor systems (El-Deek and

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El-Sabrou, 2019). Nevertheless, great variability in outdoor range use is often reported between flocks, with 4.6%–40% of chickens being observed outside (Dawkins et al., 2003; Rodriguez-Aurrekoetxea et al., 2014; Campbell et al., 2018).

There are multiples factors affecting range use by broilers. External stimuli have been studied, such as the time of the day, the weather and the outdoor area layout (e.g. trees) (Fanatico et al., 2016; Rault and Taylor, 2017). Heavy rainfall, strong wind and intense sunshine are negatively correlated with the number of chickens on the outdoor range (Rodriguez-Aurrekoetxea et al., 2014; Rana et al., 2022) while outdoor range use is positively correlated with temperature between 10 and 28 °C (Stadig et al., 2017). However, even under optimal environments, within-flock heterogeneity has been reported (Taylor et al., 2017, 2019).

Indeed, internal factors such as sex, age and strain also influence the range use by broilers at the flock level (Nielsen et al., 2003; Chapuis et al., 2011; Taylor et al., 2017). First, age influences the percentage of broilers outside, which increases by 0.3% per day (Stadig et al., 2017). Second, the total number of range visits as well as the total distance away from the barn are higher in males than in females (Ferreira et al., 2019). Third, genetics also causes variability as a comparison of eight strains showed that among different medium-growing breeds the proportion of time spent outdoors can vary from 42% in Kabir chickens to 55% in a naked-neck strain (Castellini et al., 2016).

Within flocks, individual recording of range use has revealed variation between individuals (Chapuis et al., 2011; Taylor et al., 2017; Campbell et al., 2020). A bird's personality could be a key factor that affects range use between animals. Personality traits are defined by behaviours that show within-individual consistency over time and across contexts or situations but that differ between individuals of the same species (Carere and Maestripieri, 2013). Behavioural assessments of the slow-growing S757N strain have revealed that in addition to range use potentiality to be a personality trait, social motivation and foraging evaluated before range access could also be behaviours correlated with range use (Ferreira et al., 2019, 2020, 2022).

Despite the demonstrated effects of age and genetic factors on outdoor range use, most of the aforementioned studies have relied only on only one strain or one age, or they were performed during a short time window. Data are lacking regarding how genetics impacts range use during the whole life of an animal, which would permit studying the behavioural consistency over ontogeny. We aimed to understand how genetic variability affects the broiler's personality traits, to identify early-life behavioural indicators of range use and to assess the stability of early-life indicators of range use among four broiler strains. To meet these objectives, we studied four medium- to slow-growing breeds: Hubbard JA757 (used for certified chicken production), Hubbard S757N (used for label rouge production), White Bresse (a local breed) and a dual-purpose breed (used for meat and egg production). We chose these strains based on the heterogeneity of broiler strains used on organic farms, the variability of range use among medium- and slow-growing breeds (Castellini et al., 2016) and the common practice for chicken meat production to raise a 50/50 female-to-male ratio in Europe.

2. Materials and methods

Ethical statement: this study was conducted at the experimental unit UE 1206 EASM of INRAE, France (<https://doi.org/10.15454/1.5572418326133655E12>), from February to June 2021. It received ethics committee approval (APAFIS#28675–2020120215483186 v3) in agreement with the French and European legislation, and was carried out in accordance with relevant guidelines and regulations.

2.1. Animals and housing

We studied four slow- to medium-growing breeds, Hubbard JA757 (used for certified chicken production, growth rate [GR] of 36 g/day and a rearing duration of 71 days), Hubbard S757N (used for label rouge

production, GR of 26 g/day and a rearing duration of 85 days), White Bresse (a local breed, GR of 23 g/day and a rearing duration of 106 days) and an experimental dual-purpose breed (used both for meat and egg production with a tendency for egg production for this specific strain, GR of 16 g/day and a rearing duration of 99 days). The chicks arrived on two different calendar days at the age of 1 day (day 1) from different hatcheries where they were vaccinated against Marek disease, Gumboro disease and infectious bronchitis. JA757, S757N, White Bresse and dual-purpose chicks were housed in four barns of 734, 735, 747 and 771 birds (50/50 male-to-female ratio), respectively, with one strain per barn. The barn dimensions were 12.5 × 6 m and the stocking density inside was 16.8–24.5 kg/m². Artificial lighting was continuous for the first 3 days, followed first by 3 days of lightning from 9 am until 9 pm and then by 8 days of a slow reduction of lightning hours until only natural lightning was provided. Until day 7, males and females were separated by cardboard within the barn. At day 7, all birds were identified with a wing tag and 100 male chickens per strain were chosen randomly and equipped around the neck with a plastic poncho labelled with a unique acronym for easy identification during the behavioural tests and scan samplings. Chickens had free access to the range from 36 days of age in spring 2021. All ranges measured 2500 m² (50 × 50 m). The stocking density outside was 0.5–0.7 kg/m², and the chicks had access to grass and unequally distributed trees with a density of 52–84 trees/ha. Water and 100% organic feed (including three diets characterised by 15.8 MJ/kg and 20.8% crude protein [CP] from day 1–28, 15.6 MJ/kg and 18.7% CP from day 29–57, and 15.3 MJ/kg and 17.4% CP from day 57 to the end of the rearing period) were available ad libitum. All strains had access to the same feed that was calculated according to the nutritional needs of the S757N strain, as it is the most common strain in organic systems out of the four studied strains.

2.2. Behavioural assessment of the time budget by focal sampling

For 7 days, when chicks were between 2 and 11 days old, two experimenters spent 1.5 h twice a day in the barn to habituate the chicks to their presence and to limit bias during focal sampling (Fig. 1). Equipment such as chairs needed for the focal sampling was positioned before the chicks arrived so that it was part of the environment. Focal sampling observations took place when animals were 14–19 days old (Fig. 1).

Following Altmann (1974) and Ferreira et al. (2019), behavioural observation comprised eight behavioural states that the experimenters recorded based on the duration of the behaviour (in seconds).

We established a time budget (TB) as the percentage of time spent per state behaviour during the total observation time of the experiment. The full ethogram is described in Supp. Data 1.

$$TB (\%) = 100 \times (\text{Time spent on a state behaviour in seconds}) / (30 \times 6 \times 3 = 540)$$

For a 6-day-period of behavioural observation, each individual was observed for 3 days. We recorded 6 times per day the activities of the animals for 30 s (9 min in total). Each of the two experimenters recorded the activities of 50 out of the 100 studied male broilers. To limit experimenter bias, we allowed a preliminary period of training to the ethogram before beginning this study. Inter-observer agreement was optimal for all of the state behaviours as Cohen's kappa coefficient was 0.80–1.00 (Supp. Data 2).

2.3. Social motivation and boldness behaviour assessment

To quantify variations in social motivation and boldness, we used a social motivation test and a multivariate test, following Väisänen and Jensen, (2003) and Zidar et al. (2018). We first performed the tests when the birds were between 21 and 26 days old (before range access) and repeated it when they were between 50 and 53 days old (after range access) (Fig. 1). The same experimenter conducted the test over the two periods. At each period of the testing day (between 8 am and 12 pm and

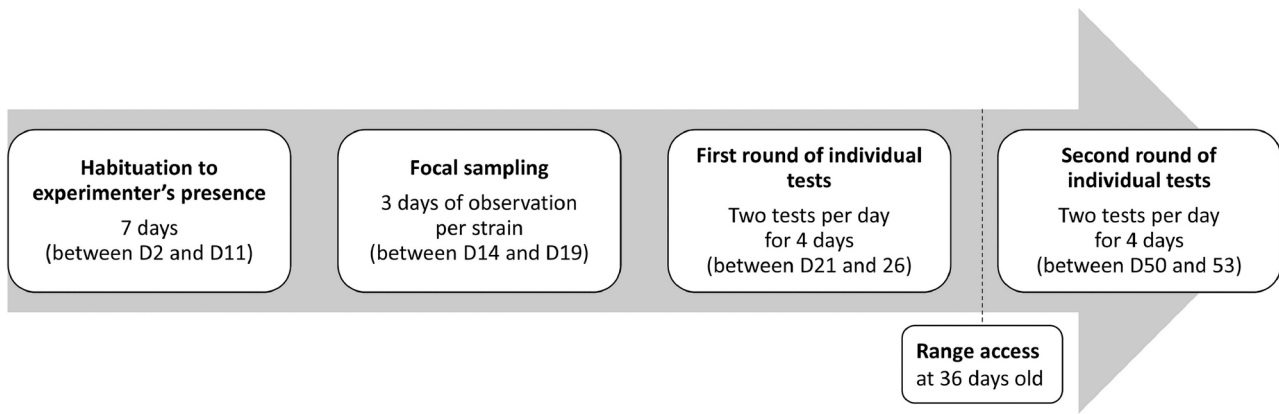


Fig. 1. Summary of the behavioural tests the birds underwent from habituation to the experimenter's presence to the second round of individual tests.

between 1 pm and 5 pm), we randomly assigned two pre-determined groups within one strain (25 individuals/group) to be tested either in the social motivation test or in the multivariate test. We tested the chickens individually in each test and submitted them to the first test situation in the morning and the second test situation in the afternoon. The following day, we submitted the 50 remaining individuals of the same strain to the tests. Thus, we tested each bird once in each behavioural test before and after range access. An experimenter directly observed behaviours outside of view of the tested animal, using a digital video camera recorder connected to a monitor.

2.3.1. Social motivation test

The arena for the social motivation test was a rectangular corridor with wooden walls and a vinyl floor divided into five marked, equal-sized areas, covered with straw for the first test and with wood chips for the second test. We covered the arena with a wire mesh to prevent individuals from escaping. We placed a dark box at one end of the corridor and a separated zone for three conspecifics at the other end of the corridor. To adapt the test to the animal's growth, we performed the test at 21–26 days of age in a $0.25 \times 0.40 \times 0.30$ m dark box and a $1.0 \times 0.4 \times 0.6$ m corridor, and performed the test at 50–53 days of age in a $0.3 \times 0.4 \times 0.6$ m dark box and a $1.6 \times 0.4 \times 0.6$ m corridor (Fig. 2a).

To reduce fearfulness and to enable the habituation of the birds to the

corridor, we allowed five randomly chosen individuals access to the corridor for 12 min. During this time, a wooden wall hid the dark box and the space for the conspecifics. Before beginning each individual test, we placed each bird in the dark box for 30 s. Then, we opened a door to provide the animal free access to the corridor for 2 min. The tested individual was able to see three conspecifics at the end of the corridor, in a separated zone. We changed the conspecifics after every five tested individuals.

The observed behaviours were the latency (seconds) to exit the box, the number of pecks (at the floor and at the environment), the number of zones visited and the time spent per zone (seconds).

2.3.2. Multivariate test

The multivariate test comprised a circular arena delimited by cardboard wall and a vinyl floor covered with straw for the first test and with wood chips for the second test. We installed four wooden panels to divide the arena into three (imagined) sections (i.e. the birds could not see these sections). We placed a wired circular arena in the centre containing three conspecifics. We surrounded the arena with curtains to prevent animals from escaping and to homogenise all the sides of the arena. To observe whether the birds used the entire arena or only parts of it, we delimited three areas: the inner circle, the outer circle and the hidden zone behind a panel area (Fig. 2b). By placing the conspecifics at the centre of the arena and the tested individual starting position in the

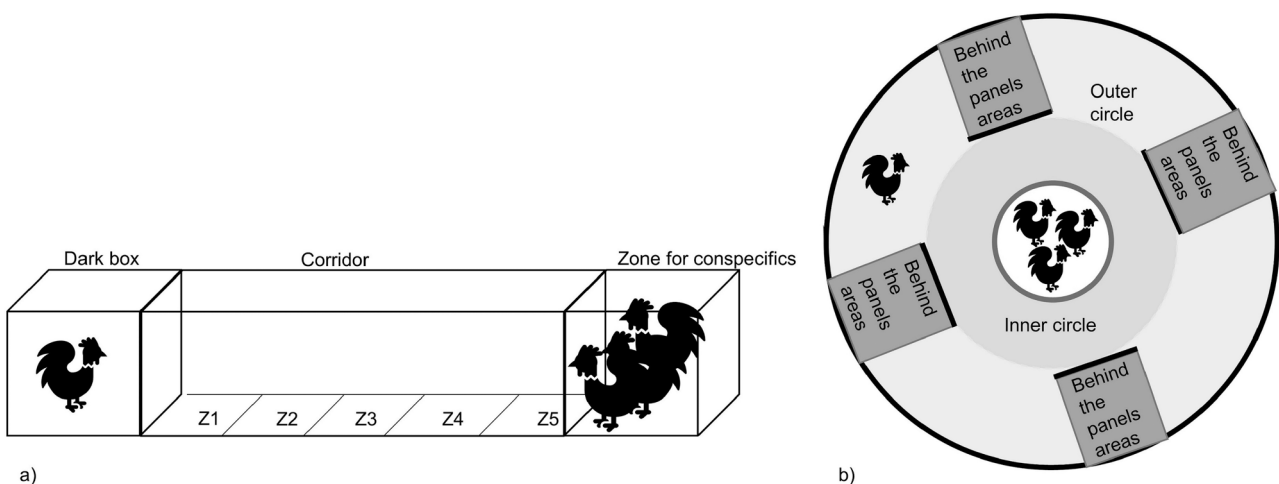


Fig. 2. Schematic figure of the apparatus used to test social motivation and the multivariate test. (a) A schematic figure of the social motivation test. The tested chicken starting position was in the dark box. The corridor was separated into five zones in order to better localise the chicken. Conspecifics were separated but always visible to the tested chicken. The zones were adapted to the animals' growth. (b) A schematic figure of the multivariate test. The black circle represents the cardboard, the black lines represent the wooden panels within the arena and the grey circle with three cartoon chickens represents the wire arena for conspecifics. The tested chicken starting position is marked with a cartoon chicken in the outer circle.

outer circle, we tested a combination of boldness, exploration and social motivation. To adapt the test to the animal's growth, the first test took place in an arena 135 cm in diameter, with 25×25 cm panels and a ring for conspecifics 35 cm in diameter; the second test took place in an arena 180 cm in diameter, with 35×35 cm panels and a ring for conspecifics 52.5 cm in diameter.

Similarly to the social motivation test, to reduce bird fearfulness and to increase their habituation to the arena, we allowed three conspecifics and the tested individual access to the wired ring for 2 min before the test. After habituation, we placed the tested individual at a predefined spot and observed it for 4 min.

The observed behaviours were the latency to make a first step (in seconds), the time spent foraging (in seconds), the number of times the chicken walked behind a wooden panel, and the time spent per area (in seconds).

2.4. Range use assessment by scan sampling

To assess the individual range use, we recorded the position on the range of the 100 identified male chickens per strain (Ferreira et al., 2019). We divided a 50×50 m range into 16 zones (Fig. 3) of similar width (12.5 m) but various lengths (5, 10, 15 and 20 m). During the scan sampling days, we performed seven evenly interspaced scans from sunrise until sunset. To record the animal position on the range and to limit animal disturbance, the experimenter walked slowly in the range in a predetermined path. The number of scan sampling records depended on the strain due to the different rearing length. We conducted 11 days of scan sampling for the JA757 strain, 12 days of scan sampling for the S757N strain and 15 days of scan sampling for the White Bresse and dual-purpose strains. All scan sampling days started when chickens were 37 days old and were interspaced by 1 or 2 days for the first 10 scan sampling days with 1 week of interruption, and by 1 week from the 11th scan sampling day.

Based on these records, we were able to calculate an individual distance index (DI) as follows:

$$DI = NT_A \times D_A + NT_B \times D_B + NT_C \times D_C + NT_D \times D_D$$

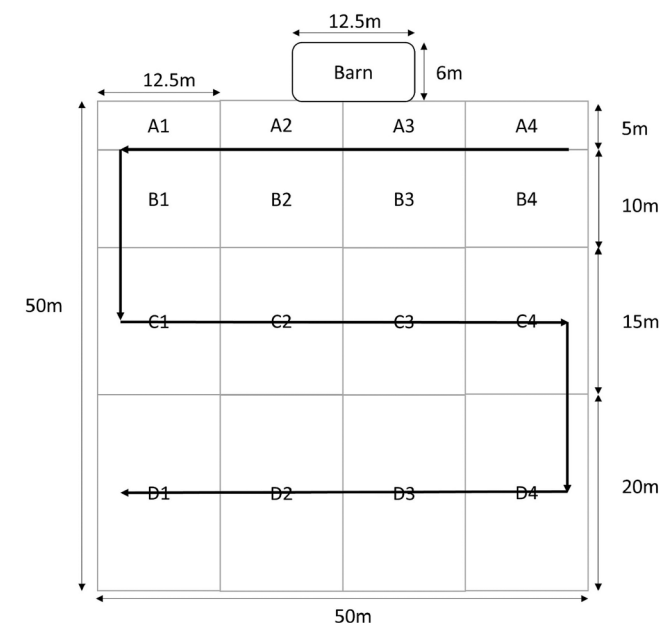


Fig. 3. A schematic of the barn and the outdoor range divided virtually into 16 different zones. Zones A–D increased in length gradually (A = 5 m, B = 10 m, C = 15 m, and D = 20 m). This range division allowed differentiating chickens who ranged near the barn from those who went further on the range. The experimenter's path is indicated by a succession of arrows.

where $NT_{(A, B, C, D)}$ is the number of times when the animal was recorded in zone A, B, C or D, and $D_{(A, B, C, D)}$ is the distance coefficient attributed to these zones. We calculated the individual DI by day of observation as a sum of the individual DI of the previous days of observation and the results of the day of observation. The individual DI after the last day of scan sampling observation is named the final distance index (FDI).

To calculate the distance coefficients for each zone, we considered that an animal recorded in a given zone was at the half-length of this zone and added this distance to the total length of the zones crossed to reach this zone. For example, a broiler seen in zone C2 would be considered 22.5 m from the barn: 5 m (length of zone A) + 10 m (length of zone B) + 7.5 m (half of zone C). Thus, the coefficients D_A, D_B, D_C, D_D are 2.5, 10.0, 22.5 and 40.0, respectively.

2.5. Statistical analysis

Our objectives were to understand how genetic variability affects the broiler's personality traits, to identify early-life behavioural indicators of range use and to assess the stability of early-life indicators of range use among four broiler strains. We performed the statistical analysis in three steps using R version 4.1.2.

Step 1: Effect of strain on early-life behaviours (before range access).

In this first step, we analysed the differences in early-life behaviours measured by focal sampling and individual tests before range access between the four studied strains with the Kruskal–Wallis test (because the data were not normally distributed). We considered differences between groups as significant when the p-value was < 0.05 . When the p-value was significant, we performed a pairwise Wilcoxon test to evaluate the variation between strains. We applied Bonferroni's correction to the pairwise Wilcoxon tests. We annotated significant differences using letters. If a behaviour in the time budget was $< 5\%$ in all four studied strains, we excluded it from the statistical analysis.

Step 2: Individual consistency of the tested variables over time.

As personality traits are defined by behaviours that showed within-individual consistency over time and across contexts or situations but differ between individuals of the same species, we evaluated the time consistency of the behaviours measured in the individual tests and scan sampling. To evaluate the stability between the two ages of measurement of behaviours from the social motivation and multivariate tests, we performed either Spearman or Pearson correlation analysis, depending on the normality of each variable. Regarding range use evaluated by scan sampling, we performed linear regression between the DI and age at the levels of the strain and the individual to evaluate the trajectory of the DI with time. We verified the normality of residuals through the Shapiro–Wilk test and graphical evaluations (histograms and Q–Q plots).

Step 3: Search for early-life behavioural indicators of range use.

First, we restricted the number of variables to be tested as potential indicators of range use; therefore, we kept only the state behaviours expressed $> 5\%$ of the time in time budget evaluated by focal sampling and we established a correlation matrix between variables recorded in the behavioural tests (social motivation and multivariate tests). For the next step, we kept only one variable when two variables were significantly and strongly correlated. Next, we explored the links between early-life behavioural variables, including variables from individual tests and focal sampling, and the FDI with Spearman correlation analysis. We considered correlations to be significant when the p-value was < 0.05 and we considered a tendency when the p-value was between 0.05 and 0.10. Additionally, we classified correlations as very high (> 0.9), high or strong (0.7–0.9), moderate (0.4–0.7), low (0.2–0.4) or weak (< 0.2) (Martin and Bateson, 2021).

3. Results

3.1. Effect of the strain on early-life behaviours (before range access)

There were significant differences in early-life behaviours among the strains, especially regarding inactive behaviours in focal sampling and in individual tests (Table 1). In fact, the dual-purpose and White Bresse strains spent almost 60% more time standing than the JA757 strain. On the contrary, the JA757 strain spent almost 50% more time resting than the White Bresse and dual-purpose strains, while the S757N strain showed intermediate values for these two behaviours. The strains also differed in their sleeping behaviour, which was lower in the dual-purpose strain than in the S757N and White Bresse strains; the JA757 strain showed intermediate values.

Regarding the social motivation test, the dual-purpose strain needed 35–76% more time to exit from the dark box and 11–45% more time to arrive to the zone close to conspecifics. The two strains with the lowest time to exit (White Bresse and JA757) also showed more exploratory pecks to the environment than the two other strains.

Finally, in the multivariate test, the White Bresse strain spent 1.6–2.2 more time foraging than the S757N and JA757 strains and went 3–4.5 times more often behind the panel than the other breeds. The White Bresse and S757N strains also had a much lower latency to move in this test than the JA757 and dual-purpose strains.

3.2. Individual consistency of the tested variables over time

3.2.1. Individual tests

We calculated correlations between the measurements from both rounds of individual tests (Table 2).

Table 1

Mean early-life behaviours in the JA757 (n = 100), S757N (n = 97), White Bresse (n = 98) and dual-purpose (n = 99) strains.

	JA757 (n = 100)	S757N (n = 97)	White Bresse (n = 98)	Dual- Purpose (n = 99)	p-value
State behaviour recorded during focal sampling (relative %)					
Standing	18.4 ^c	25.0 ^b	29.5 ^{ab}	29.3 ^a	< 0.001
Resting	25.6 ^a	20.3 ^b	17.6 ^b	17.0 ^b	< 0.001
Sleeping	9.2 ^b	11.8 ^a	12.1 ^a	6.1 ^c	< 0.001
Locomotion	10.5	9.9	8.3	8.7	0.059
Foraging	19.3	18.3	19.0	21.8	0.136
Drinking & Eating	13.0	13.3	11.7	14.7	0.310
Variables of the social motivation test					
Latency to exit (s)	78 ^{bc}	82 ^b	63 ^c	111 ^a	< 0.001
Latency to arrive to the zone close to conspecifics (s)	106 ^b	107 ^b	82 ^c	119 ^a	< 0.001
Number of pecks	2.6 ^a	0.8 ^b	2.2 ^a	0.1 ^c	< 0.001
Variables of the multivariate test					
Latency to make a first step (s)	12.6 ^{ab}	2.2 ^b	3.5 ^b	19.5 ^a	< 0.001
Foraging (s)	52 ^c	74 ^b	115 ^a	95 ^{ab}	< 0.001
Number of times the chicken walked behind a wooden panel	0.2 ^b	0.3 ^b	0.9 ^a	0.2 ^b	< 0.001
Time in the outer circle (s)	50	27	34	40	0.086

Bold numbers indicate significant differences among strains ($p < 0.05$). Different superscripts within the same variable indicate significant differences between strains ($p < 0.05$).

For the social motivation test, in the White Bresse strain there were significant low and positive correlations between the first and second rounds of test for the latency to exit, the latency to arrive in the zone close to conspecifics and the number of pecks. There was also a significant low and positive correlation in the JA757 strain between the two rounds of test for the latency to arrive in the zone close to conspecifics.

For the multivariate test, there were significant low and positive correlations for the dual-purpose strain between the two periods for the latency to make a first step and the time spent in the outer circle. There was a significant low and positive correlation for the JA757 strain for the time spent in the outer circle.

3.2.2. Range use

For each strain independently, we measured the evolution of range use over time by considering the individual DI by day of observation until the FDI. At the level of the strain including the FDI for 100 individuals per strain, range use increased with time but we observed a relatively poor quality of adjustment (adjusted R^2 0.16–0.49) in the linear regression between the FDI and the age of measurement (Supp. Data 3). This means that due to inter-individual variability in range use, we could not draw a conclusion regarding the time consistency of range use at the strain level. By contrast, we found a strong linear relationship between the FDI and the age at the level of the individual, indicating that within-individual range use is consistent over time. Indeed, the adjusted R^2 coefficient of the linear regression was > 0.7 for 82–99% of the individuals depending on their strain (Supp. Data 4).

The mean FDI for the JA757, S757N, White Bresse and dual-purpose strains was 217, 301, 837 and 202 m, respectively. Depending on the strain, the minimum FDI varied from 0 to 137 m and the maximum FDI varied from 765 to 2449 m. The FDI median and quartiles also varied depending on the breed (Fig. 4).

3.3. Search for early-life behavioural indicators of range use

We calculated correlations between variables measured before birds had access to the range (behavioural assessment of the time budget and the first round of the social motivation and multivariate tests) and the FDI. We noted significant correlations or tendencies in all breeds (Table 3).

The time spent foraging was the behaviour most frequently correlated with the FDI among the tests and strains. Indeed, for the JA757 strain, foraging during focal sampling was positively correlated with the FDI ($\rho = 0.29$, $p = 0.01$) and it tended to be positively correlated with the FDI ($\rho = 0.17$, $p = 0.10$) in the first multivariate test. We observed a similar tendency for the White Bresse strain, with a tendency for a positive correlation between foraging during focal sampling and the FDI ($\rho = 0.17$, $p = 0.09$). Finally, for the dual-purpose strain, the time spent foraging in the first multivariate test was significantly and positively correlated with the FDI ($\rho = 0.21$, $p = 0.04$).

Considering the JA757 strain, locomotion was significantly and positively correlated with the FDI and sleeping during focal sampling was significantly and negatively correlated with the FDI. Rest and drinking and eating during focal sampling tended to be negatively correlated with the FDI ($\rho = -0.17$, $p = 0.09$). Finally, for the S757N strain, only the time spent in the outer circle during the first multivariate test was significantly and positively correlated with the FDI ($\rho = 0.20$, $p = 0.05$).

4. Discussion

We aimed to understand genetic variability in personality traits, to identify early-life indicators of range use and to assess its stability among four broiler strains. We chose to study only males because previous studies have shown a sex effect in favour of males for outdoor use (Chapuis et al., 2011; Ferreira et al., 2019). First, we checked whether early-life behaviours varied depending on the strain, while the chickens

Table 2

Mean (+ standard deviation) of behaviours observed during the first and second round of tests and Spearman correlations between the variables at the first and second rounds of individual test for the JA757 (n = 100), S757N (n = 97), White Bresse (n = 98) and dual-purpose (n = 99) strains.

	JA757 (n = 100)				S757N (n = 97)				White Bresse (n = 98)				Dual purpose (n = 99)			
	1st round	2nd round	rho	p	1st round	2nd round	rho	p	1st round	2nd round	rho	p	1st round	2nd round	rho	p
Variables of the social motivation test																
Latency to exit (s)	78 ± 45	85 ± 46	0.08	0.43	82 ± 45	79 ± 49	0.12	0.22	63 ± 46	42 ± 49	0.33	< 0.001	111 ± 31	81 ± 51	0.03	0.76
Latency to arrive in the zone close to conspecifics (s)	106 ± 27	101 ± 33	0.20	0.05	107 ± 30	95 ± 41	0.14	0.17	82 ± 41	64 ± 48	0.27	0.01	119 ± 5	104 ± 35	-0.05	0.60
Number of pecks	2.6 ± 7.8	2.4 ± 7.3	0.01	0.92	0.8 ± 2.4	5.1 ± 13	0.11	0.26	2.2 ± 4.3	6.7 ± 14	0.20	0.05	0.1 ± 0.8	1.0 ± 3.5	-0.04	0.71
Variables of the multivariate test																
Latency of first step (s)	13 ± 36	22 ± 58	<i>0.17</i>	<i>0.09</i>	2.2 ± 5.0	22 ± 62	-0.09	0.39	3.5 ± 13.0	2.0 ± 5.9	0.05	0.62	19 ± 49	27 ± 72	0.35	< 0.001
Foraging (s)	52 ± 68	19 ± 27	0.02	0.84	74 ± 53	40 ± 51	0.15	0.14	115 ± 56	58 ± 54	-0.11	0.26	95 ± 77	24 ± 32	0.11	0.30
Occurrences of walk behind the panel	0.2 ± 0.6	0.0 ± 0.0	-	-	0.3 ± 0.9	0.1 ± 0.3	0.00	0.99	0.9 ± 1.6	0.0 ± 0.1	-0.11	0.29	0.2 ± 0.6	0.1 ± 0.5	0.16	0.11
Time in the outer circle (s)	50 ± 62	32 ± 64	0.21	0.04	27 ± 40	44 ± 71	0.05	0.64	34 ± 42	15 ± 21	-0.02	0.85	40 ± 61	40 ± 72	0.26	0.01

Bold numbers indicate significant differences between the first and second rounds of individual tests ($p < 0.05$).

Italic numbers indicate tendencies for differences between the first and second rounds of individual tests ($0.50 \leq p < 0.10$).

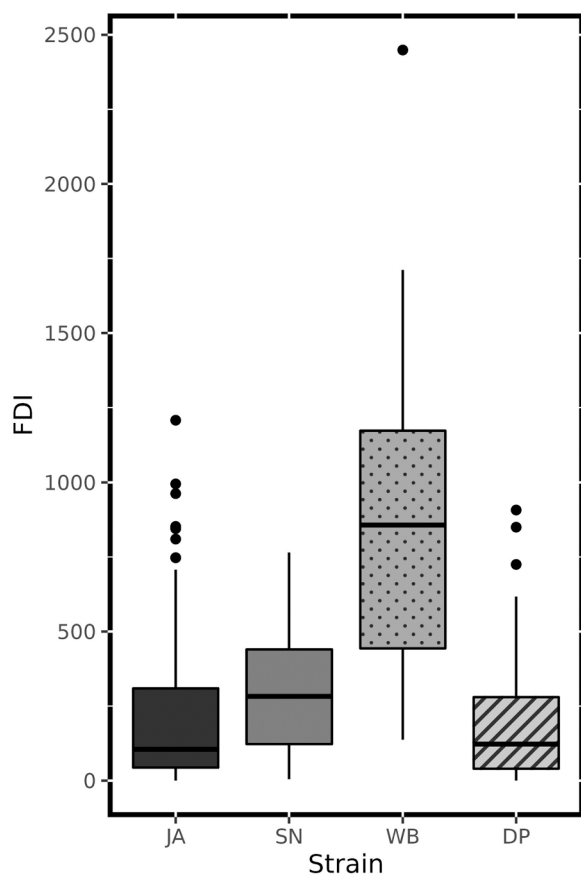


Fig. 4. Boxplot representing the median and quartiles of the final distance index (FDI) of male broilers from the JA757 (JA, n = 100, 11 days of scan sampling), S757N (SN, n = 97, 12 days of scan sampling), White Bresse (WB, n = 98, 15 days of scan sampling) and dual-purpose (DP, n = 99, 15 days of scan sampling) strains.

are reared indoor without access to the free range. Second, we determined whether social motivation, boldness, exploration and range use are personality traits by evaluating the time consistency of these behaviours while controlling for the genetic impact. Third, we searched for early-life behavioural indicators of range use and we checked whether genetic variation influenced the correlations between early-life behavioural indicators and range use.

4.1. Strain effect on early-life behaviours

We found significant differences in behaviour between the four studied strains when birds were still inside and < 36 days old. Indeed, the mean relative percentage of time standing in the barn was lower for the JA757 strain compared with the S757N, White Bresse and dual-purpose strains, while resting represented a higher proportion of the time budget for the JA757 strain compared with the S757N, White Bresse and dual-purpose strains. These results might be related to the GR of the JA757 strain – a daily weight gain of 36 g/day, much higher than the slow-growing S757N, White Bresse and dual-purpose strains (daily weight gains of 26, 23 and 16 g/day, respectively). Additionally, the mean relative percentage of time spent sleeping was lower for the dual-purpose strain compared with the JA757, S757N and White Bresse strains while standing represented a higher allocated time compared with the JA757 and S757N strains. The dual-purpose strain in this study comes from a laying hen strain, which has been shown to be more fearful (Albentosa et al., 2003; Nelson et al., 2020). Fearfulness can be evaluated by tonic immobility as well as the duration of vigilance behaviour (Odén et al., 2005). Therefore, the greater time allocated standing and the lower time allocated resting and sleeping by the dual-purpose strain might be the expression of greater vigilance behaviour (Beauchamp, 2015) compared with the three other strains.

After the chickens from each strain were allowed to access the free range at 36 days of age, we observed their range use. Because factors such as the temperature at the time we opened the traps (Dawkins et al., 2003; Stadig et al., 2017), which occurred on different dates, and the design of the outdoor ranges, especially the location of trees (Supp. Data 5), may have influenced the inter-strain range use (Dal Bosco et al., 2014; Stadig et al., 2017), we decided to consider range use and behaviour within each strain. Nevertheless, more cautiously, we did

Table 3

Spearman correlations between the variables of early-life behaviours of male free-range broilers, in their home environment (focal sampling) and in the individual tests (the social motivation and multivariate tests before range access), and the final distance index assessing the range use of the JA757 (n = 100), S757N (n = 97), White Bresse (n = 98) and dual-purpose (n = 99) strains.

	JA757 (n = 100)		S757N (n = 97)			White Bresse (n = 98)		Dual-Purpose (n = 99)	
	rho	p	rho	p	rho	p	rho	p	
State behaviours recorded during focal sampling (in relative %)									
Standing	0.01	0.92	0.01	0.89	-0.02	0.88	-0.13	0.21	
Resting	<i>-0.17</i>	<i>0.10</i>	0.06	0.55	-0.08	0.41	-0.01	0.92	
Sleeping	-0.24	0.01	0.06	0.55	0.02	0.85	0.07	0.48	
Locomotion	0.26	0.01	0.09	0.38	-0.01	0.91	0.08	0.45	
Foraging	0.29	0.01	-0.02	0.87	0.17	0.09	0.07	0.48	
Drinking & Eating	<i>-0.17</i>	<i>0.09</i>	-0.12	0.25	-0.02	0.82	0.06	0.54	
Variables of the social motivation test									
Latency to exit (s)	-0.09	0.35	-0.04	0.69	-0.08	0.44	-0.01	0.91	
Latency to arrive to the zone close to conspecifics (s)	-0.13	0.19	0.05	0.62	-0.10	0.33	0.09	0.36	
Number of pecks	0.03	0.77	-0.14	0.17	-0.06	0.53	-0.09	0.36	
Variables of the multivariate test									
Latency of first step (s)	-0.09	0.38	0.05	0.65	0.07	0.49	0.03	0.75	
Foraging (s)	<i>0.17</i>	<i>0.09</i>	0.04	0.71	0.00	0.97	0.21	0.04	
Occurrences of walk behind the panel	0.05	0.60	0.03	0.80	-0.04	0.71	-0.06	0.59	
Time in the outer circle (s)	0.02	0.86	0.20	0.05	0.00	0.97	0.02	0.88	

Bold numbers indicate significant rank correlations ($p < 0.05$) and italic numbers indicate tendencies for rank correlations ($0.50 \leq p < 0.10$).

consider inter-strain differences after range access.

4.2. Time consistency of behaviours

In the present study, we observed the time consistency of range use by individuals (but not groups), denoted by significant linear regressions of the DI with age. Therefore, range use showed within-individual consistency over time but differed between individuals of the same strain. Similarly, [Ferreira et al., \(2019, 2020, 2022\)](#) showed time consistency in range use behaviour across the season for the S757N strain: the number of range visits was significantly and positively correlated between early-life range access and late range access. Based on these findings, range use seems to be a personality trait as it shows within-individual consistency over time and across contexts or situations but differs between individuals of the same species ([Carere and Maestriperi, 2013](#)).

Social motivation, boldness and exploration seemed to change with animals' age as we found few significant correlations between the variables for the first round of test (before the animals had access to the outdoor range) and the second round of tests (after the animals had access to the outdoor range). Accordingly, the S757N strain showed no consistency in the time spent near conspecifics in the social motivation test ([Ferreira et al., 2022](#)). In Red Junglefowl, the domestic chicken's ancestor, birds spent more time with unknown conspecifics but preferred to forage than to socialise in a choice test. This phenomenon might indicate a trade-off between social motivation and exploration ([Väisänen and Jensen, 2003](#)). Therefore, we hypothesise that for the S757N, JA757 and dual-purpose strains, exploration becomes more important than social motivation with age. This view would explain the absence of time consistency regarding social motivation for these strains.

Social motivation might be time consistent in the White Bresse strain. Indeed, we found low but significant correlations ($0.2 \leq \rho < 0.4$) between the variables of the first and second round of the social motivation test, suggesting that social motivation might be more time consistent for this strain than for the other three strains. Compared with the other strains, the White Bresse strain exhibited early sexual maturity behaviours at the end of the rearing period. It seems that its ontogeny differs from the other studied breeds and that their precocity may be associated with an earlier establishment of consistent social behaviour over different age periods.

Boldness might be time consistent in the dual-purpose strain. Regarding the multivariate test for this strain, we observed a significant low and positive correlation between the latency to make a first step and the respective variables in the second round and we noticed a significant low and positive correlation between the time spent in the outer circle in the first round and the respective variables in the second round. Based on previous studies, boldness is inconsistent over individual ontogeny ([Carere et al., 2005](#); [Hedrick and Kortet, 2012](#); [Herde and Eccard, 2013](#)), with a major influence of sexual maturity on males. The lower GR and potentially greater fearfulness of the dual-purpose strain relative to the other studied strains might result in the time consistency of boldness between the relatively young ages of the two rounds of individual test.

Finally, we observed two significant low and positive correlations and one weak correlation between the first and second rounds of tests for the JA757 strain. Although reared under organic regulations, the JA757 strain GR can be qualified as intermediate (36 g/day). This strain's personality traits might be fixed faster than the slow-growing S757N strain, explaining the time consistency of several behavioural measures.

4.3. Early-life predictors of the FDI

Based on previous research on individual ranging behaviour of broiler ([Mattioli et al., 2021](#); [Ferreira et al., 2022](#)), we expected that locomotion and foraging measured in young birds in the barn (before access to the outdoors) would be significantly and positively correlated with the DI and that inactive behaviours and social motivation would be significantly and negatively correlated with the DI. Our expectations were partially met in the JA757 strain as higher range use was associated with animals spending more time moving and foraging and less time sleeping and resting. In our study, only the JA757 strain showed a significant and positive relationship between foraging in the time budget and range use. Foraging was also significantly and positively correlated with range use in the dual-purpose strain (in the first multivariate test) and there was a tendency for a positive correlation in the White Bresse strain (in the time budget), but not in the slow-growing S757N strain.

Yet, as boldness and foraging are intertwined behaviours ([Réale et al., 2007](#)), the correlation between the time spent in the outer circle in the first multivariate test and range use in the S757N strain might be the precursor of a significant and positive correlation between foraging and range use in the second round of multivariate test ($\rho = 0.27$, $p = 0.01$, Supp. Data 6). This eventuality would be consistent with a previous

study in this strain reporting that the foraging behaviour was a predictor of range use at three different ages and two different seasons (Ferreira et al., 2022). On the contrary, we did not confirm the results of Ferreira et al. (2020), who found a significant correlation between social motivation and range use within the S757N strain. This might be due to the outdoor range design because, in these previous studies, broilers were reared in a meadow-like range (Ferreira et al., 2020, 2022), whereas our outdoor areas were covered with mature trees. Studying the social network of broilers might help to understand how social motivation and range use are correlated. Indeed, clear correlations indicated that more closely (socially) associated individuals were also more similar in their movement patterns (Gómez et al., 2022) when studying social network of hens and individual stable social associations.

5. Conclusion

We aimed to understand broiler's personality traits and their relation to range use in several strains. We found that early-life behaviours expressed by each individual within a strain, such as inactive behaviours and behaviours recorded during the multivariate or social motivation tests, might depend on the strain. Additionally, individual range use seems to be part of a stable personality trait regardless of the strain. Ontogeny might influence sociability, boldness and exploration but, depending on the strain, some personality traits might be stable over time for young broilers before sexual maturity, such as social motivation, boldness and exploration evaluated by the individual tests in our study. Finally, we found little evidence that early-life behavioural indicators could be robust predictors of the range use behaviours independently of the strain. However, the multiple correlations between foraging behaviour and range use call for further investigations. Therefore, understanding the behavioural precursors of range use among several common organic breeds will be a challenge for the future.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.applanim.2023.105870](https://doi.org/10.1016/j.applanim.2023.105870).

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