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Assessing the motivation of laying hens to outdoor space access

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ABSTRACT

The present study aimed at evaluating the motivation of laying hens to access outdoor space and their behavior under indoor and outdoor conditions. A total of 54 laying hens (White Leghorns) at 38 weeks of age were housed in two experimental groups: indoors, 3 replicates of 9 hens each (10 hens/m^2), and outdoors, 3 replicates of 9 hens each (10 m^2/hen). The behavioral evaluation was performed using a video recording system, and the videos were analyzed using a scan sampling method. The motivation test was carried out in one of the replicates (9 hens in total) with outdoor access. To access the feed (used as gold standard) and to the outdoor area, hens had to push a transparent one-way door with increasing weight (100 g every two days). The test was interrupted when each hen did not pass through the door for two consecutive days. The motivational drive to access the two settings (i.e., feed and outdoor space) was quantified by constructing a behavioral demand function and calculating various indices based on economic theories. The number of visits per hen decreased when the door weight increased in both groups ($P < 0.001$). Nevertheless, while no hen reached the feed when the door weighed 650 g, hens opened the door up to a weight of 750 g to access the outside space. Reservation price (the maximum weight each hen pushed to access a specific resource) and total travel consumer surplus (the cumulative effort exerted by each hen during the test to reach a specific resource) averaged 445 g and 6.881 kg, respectively, without differences between resources. Moreover, the budget allocation was similar for feed and outdoor space. However, the demand for outdoor access resulted in a more inelastic trend than that for feed ($P = 0.002$), and the expenditure rate (the daily effort exerted by each hen during the test to reach a specific resource) was significantly higher for outdoor space as compared to feed ($P < 0.001$). In the group with access to an outdoor area, finally, the proportion of hens walking and self-grooming increased, while the proportion of hens resting decreased compared to the group kept indoors ($P < 0.001$). In conclusion, the present study demonstrates that laying hens are highly motivated to access outdoor space where they can find grass and other valuable resources and perform species-specific behaviors.

1. Introduction

For the poultry industry, there is increasing attention directed towards welfare issues. Most of the studies are primarily focused on evaluating the impact of the housing environment on animal welfare by investigating different aspects, including stocking density (Shynkaruk et al., 2023), heat stress conditions (Cartoni Mancinelli et al., 2023a), different litter material (Holt et al., 2023), among others. In this context, the use of environmental enrichments is widely employed as a mean to enhance animal welfare (Nazareno et al., 2024; Vas et al., 2023). The enrichment could be defined as an "*improvement in the biological functioning of captive animals resulting from modifications to their environment*" (Newberry, 1995). Environmental enrichments can support immune function by introducing mild stressors that foster adaptability, a principle that also applies to free-range pullets adapting to diverse outdoor conditions. Additionally, complex rearing systems may offer various benefits, such as reducing fear, which can facilitate a smoother transition to the layer facility (Campbell et al., 2018).

In chickens housed in alternative systems (i.e., free-range and organic), the presence of pasture can be considered an environmental

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enrichment that gives animals a stimulus to engage in species-specific behaviors to exploit the available resources (i.e., grass, space, fresh air, sunlight). Farming systems that allow access to outdoor areas have always been seen as more respectful of welfare (Fraser, 2008) and are today one of the most important recommendations of the European Union (European Commission, 2020). They provide more complex environments and resources that align with species-specific behavioral needs and may enhance the likelihood of stimulating a positive affective state (Anderson et al., 2021). It is well known that animals, including chickens, raised in an outdoor area exhibit a larger ethogram than those housed in conventional systems (Thuy Diep et al., 2018). It can stimulate the animal's motivation to exploit the provided environmental resources, thus enhancing its life quality (Jacobs et al., 2023). However, the use of the outdoor area and grazing ability are closely linked to the genotype (Cartoni Mancinelli et al., 2021). In Europe, there is an ongoing debate about finding appropriate tools and methodologies to assess the chicken's adaptability to alternative housing systems. Thus, a further challenge is how to evaluate changes in the chicken's quality of life.

Modern approaches to animal welfare, such as Quality Of Life (**QOL**) and Affect Balance concepts, integrate traditional welfare evaluation with a consideration of the balance between positive and negative experiences that characterize animal life (Yeates, 2016). They also emphasize the concept of "positive welfare", recognizing the importance of offering animals not only the alleviation of suffering but also the opportunities for positive experiences. Despite the challenge of identifying animals' emotional states and categorizing behaviors as positive or negative, observing their behavior, motivation, and choices can help define their QOL and enhance understanding of adaptability and welfare status in a specific environment (Duncan, 2005; Mellor, 2012).

In this context, behavioral observations and motivation tests could serve as valuable methods for assessing animal welfare, particularly in understanding the emotional states and experiences of animals regarding environmental changes, such as the presence of an outdoor area (Hughes and Duncan, 1988; Jensen and Toates, 1993). Motivation tests imply that the animal is required to pay a cost of some kind (e.g., operant "work") to gain access to the resource of interest. In this way, motivational tests not only can establish whether an animal is motivated to obtain (or avoid) the resource, but they also quantify the strength of this motivation (Kirkden, 2006). Moreover, the animals' motivation to engage in a specific activity to reach a reward is strictly linked to positive experiences (Mellor, 2016; Menchetti et al., 2021). Several ethological and neurobiological evidence support the idea that the implementation of motivated behaviors is associated with positive experiences, just as the deprivation of motivated behaviors is associated with frustration and poor welfare (Boissy et al., 2007). Thus, it could be hypothesized a positive relation between effort to achieve a resource, strength of motivation and positive perception of that resource. Ultimately, motivation tests could evaluate how the animal perceives a certain resource (Buijs et al., 2011).

A common approach to quantifying animals' motivation is to impose an increasing cost for accessing resources or performing specific behaviors (Jensen and Pedersen, 2008). The results of these tests can be interpreted using economic principles such as the price elasticity of demand, the slope of the demand curve, and economic theory (Kirkden, 2006). This approach estimates the effort an animal is willing to exert to access a resource or engage in behavior as a measure of the strength of motivation. Therefore, the presence of valuable resources or the expression of highly motivated behaviors enhances animal well-being, whereas their absence may diminish it (Jensen and Pedersen, 2008).

Since feed is a vital resource for animals, it is commonly used as a gold standard in motivational tests to measure the actual motivation towards the resource under study (Bokkers et al., 2004; Seaman et al., 2011). While motivational tests have been previously applied to assess the motivation of laying hens to perch (Olsson and Keeling, 2002), have access to nest sites (Kruschwitz et al., 2008), forage (Dixon et al., 2014) or dust bathe in appropriate substrates (Wichman and Keeling, 2008), there is no study on the motivation of hens to access valuable conditions such as outdoor space. Nonetheless, assessing the animals' motivation towards valuable environments and evaluating their behavioral patterns under these conditions are crucial milestones in defining positive behaviors and affective states in poultry.

The hypothesis is that birds will exert considerable effort to access a valuable outdoor space, where they can benefit from additional space and resources such as grass, fresh air, and sunlight. This effort is expected to be comparable to that required to obtain a primary resource like feed. Once they gain access to an enriched environment, they are expected to engage in behaviors indicative of a positive affective state, triggered by the availability of such a valuable condition.

In view of the above, the aims of the present study were i) to quantify the motivation of laying hens to access an outdoor area through a motivational test, and ii) to evaluate the different behavioral repertoire expressed by hens reared both in indoor and outdoor conditions through behavioral observations. In particular, the motivation for the outdoor area was evaluated through an operant test where an increasing weight was applied to a one-way transparent pushing door, and feed was used as the gold standard. Moreover, to better interpret the relationship between behavioral change and increasing costs related to the importance of the resource, several indices usually adopted in the human economy were applied.

2. Material and methods

2.1. Ethic statement

Animals were reared according to EU Regulation 74/1999, and the Italian directives on animal welfare for experimental and scientific purposes (EU Regulation 63/2010). The Bioethical Committee of the University of Perugia (Italy) positively evaluated and approved the experimental protocol (Protocol Number ID: 76527).

2.2. Animals, experimental design, and housing conditions

The present study was carried out from October to November 2022 in the experimental section of the Department of Agricultural, Food and Environmental Sciences (University of Perugia, Italy).

A total of 54 laying hens (white Leghorns) at 34 weeks of age (1589 ± 8 g body weight average) were used for this research purpose. Hens came from the same biodiversity flock farmed in our experimental facility and were randomly allocated into two experimental groups: indoor, 3 replicates of 9 hens each (9 hens/m^2), and outdoor, 3 replicates of 9 hens each (10 m^2/hen).

All six pens used in this trial were located in the same building adjacent to one another and characterized by the same dimensions (length 1.00 m, width 1.00 m, and height 1.90 m). Inside, the pens had a concrete floor bedded with wood shavings as litter (height 5 cm, 2.5 kg/m^2). Each pen was equipped with a circular drinker (diameter: 39 cm) and a circular feeder (diameter: 37 cm) for manual distribution of water and feed, two individual nests (one nest each 7 hens) and linear cylindrical perch (diameter 40 mm) ensuring 15 cm/hens. In the three pens (Fig. 1a) characterized with the outdoor access, hens had a direct access to the external area by a transparent door (height 35 cm and length 40 cm). The outdoor area was covered by spontaneous grass (not cultivated and not treated with fertilized and pesticide) and individually delimitated by a shaded metallic net height of 1.90 m and placed 0.40 m under the ground in order to protect hens from predators during the day, while during the night, hens were kept indoors. Thus, animals in the same pen were able to see the outdoor area and their conspecifics outside (through the transparent door). On the contrary, no visual contact was possible between animals of adjacent pens.

A commercial diet (CP 16 % and EM 2680 Kcal) and water were provided *ad libitum*.

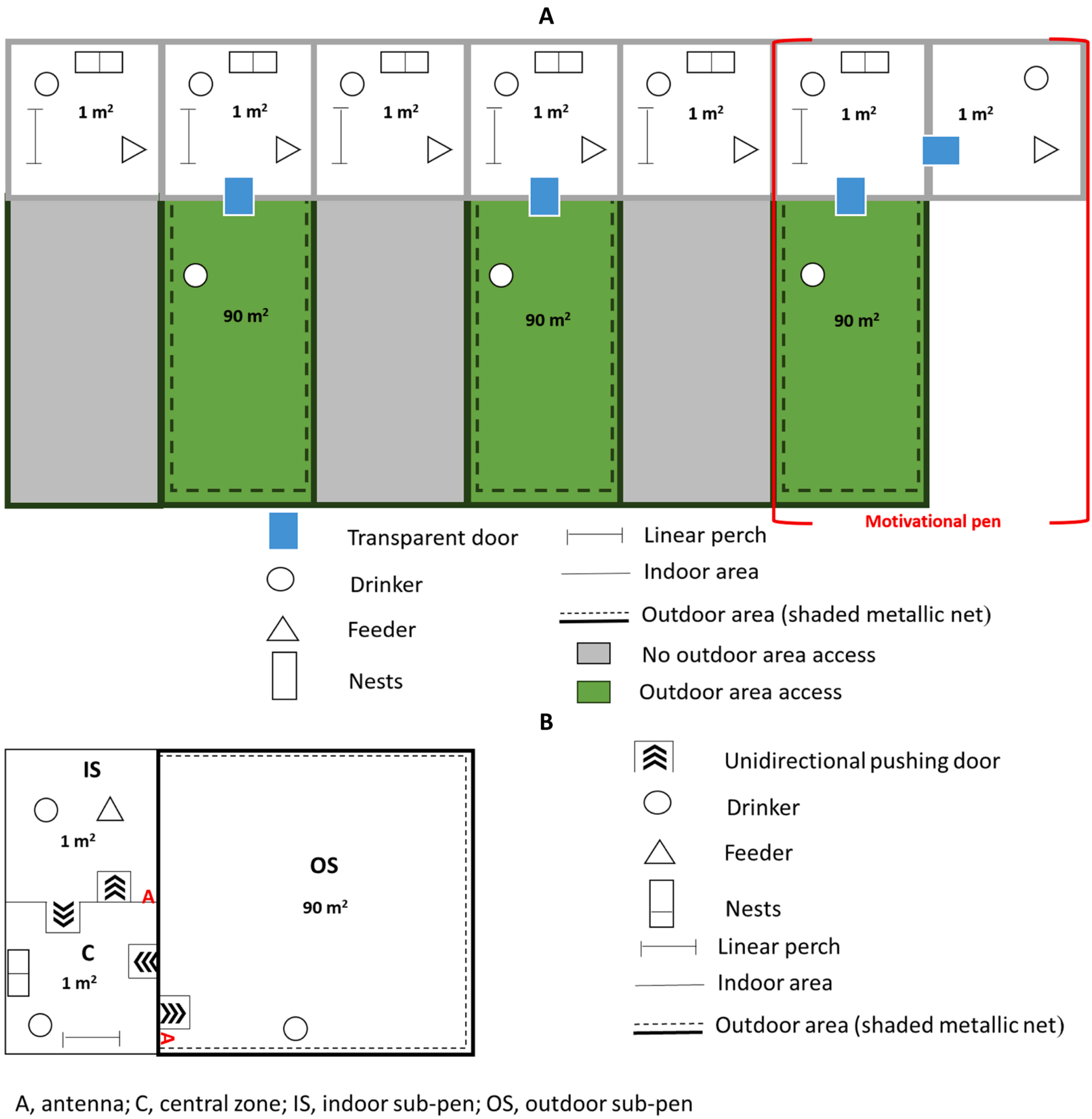

Fig. 1. Schematic representation of the pens disposition (**A**), and representation of the motivational pen (**B**).

Two weeks of adaptation (weeks 34 and 35 of age) were provided to the hens before the beginning of the trial. Throughout the trial (from weeks 36–42), all hens were subjected to a natural photoperiod of approximately 10 hours of light (from 6 am to 5 pm) and 14 hours of darkness.

For the entire length of the trial, outside temperature was recorded by an external thermometer. The average temperature during the day was 11.4 °C with a maximum of 15.4 °C and a minimum of 6.4 °C (reached during the night).

2.3. Motivation test

One of the pens with access to outdoor space was supplied with a particular equipment specifically designed to perform a motivational test. The nine White Leghorn hens housed in the motivation pen were uniquely identified by a ring provided with an alphanumeric code chip.

The motivation pen (Fig. 1b) was characterized by:

- An indoor central zone (**C**, 1.0 m^2) equipped with nests and drinkers.
- An indoor sub-pen (**IS**, 1.0 m^2) connected to the C zone by two one-way transparent pushing doors positioned at 30 cm from each other (plexiglass material, dimensions of 210 × 297 mm/each). This area was equipped with a feeder and drinker.
- An outdoor sub-pen (**OS**, 90 m^2; space allowance 10 m^2/hen) connected to the C zone by two one-way transparent pushing doors

positioned at 30 cm from each other (plexiglass material, dimensions of 210 × 297 mm/each). This area was equipped with a drinker.

A monitoring system (ChickenGate, Luna Geber Engineering—LGE s.r.l., Perugia, Italy) recorded the animals entering the different sub-pens (IS and OS). The ChickenGate system includes a half-sphere antenna (**A**) placed near the pushing door used by the hens to reach each sub-pen. This system was able to read the hens' chips and send the recorded data to a computer. The collected raw data was organized in an Excel file reporting the animal's identification code, the day, and the time of each visit to the sub-pens. All the equipment was positioned before the hens arrived so that it was part of the environment.

For two weeks (36 and 37 weeks of age), hens were trained to access all the different sub-pens (IS and OS) through push doors without weights. This training period was assessed to allow the animals to get confident with the pushing-door mechanisms and to check, comparing with direct observations, both the proper functioning and data recording of the ChickenGate system.

During this period, feed and water were provided *ad libitum*. After the adaptation period, the motivation test was performed.

The motivational test was carried out through two different tests, spatially and temporally divided, using the same methodology:

1st test - feed resource motivation test (gold standard)

2nd test - outdoor resource motivation test

2.4. Feed resource motivation test

The first test assessed the hen's motivation to access feed, which served as the gold standard. This evaluation took place during weeks 38 and 39 of age.

Thus, the C and IS areas of the motivational pen were used, and consequently, the animals were not allowed access to the outdoor area. As described above, the feed resource was placed only in the IS sub-pen.

To access the resource, the animals had to pay a cost consisting of a weight applied to the one-way transparent pushing door (Fig. 1b). This door allowed animals to move from the C zone to the IS zone. No weight was placed on the door leading from IS to C so that animals could re-enter at no cost. The door weight was set at 150 g on day 0 and increased by 100 g every 2 days to allow the animals to adapt to the effort. Data on the proportion of hens passing through the door to reach the resource (expressed as a percentage of the present animals) and the number of visits made by each hen per day were reported as the average over the 2 days during which the door had the same weight. The observation range of the motivation test was from 8 am to 6 pm.

At the end of each day, the Excel file with feed resource visits generated by the ChickenGate system was downloaded. For each hen, the test was considered closed when they did not pass through the door for two consecutive days. No hen was removed from the group until the test closed for all hens. Every evening at 6 pm, 90 g/hen of feed was provided (Bokkers et al., 2004). This amount of feed covered the requirements for maintenance and egg production, but it did not completely satisfy their appetite. This strategy was deemed effective in ensuring animal welfare (providing access to a sufficient quantity of feed) while avoiding satiation.

2.5. Outdoor resource motivation test

The second test assessed the hens' motivation to access the outdoor area covered with outdoor space resources. This evaluation took place during weeks 40 and 41 of age.

For this test, the C, IS, and OS areas of the motivation pen were used. Feed was placed only in the IS sub-pen. Since the pushing doors were removed, animals had free access to the feed resource (from C to IS). However, to access the outdoor space resource, animals had to pay a cost consisting of a weight applied to the one-way transparent pushing door (Fig. 1b), which permits animals to access the OS zone from the C one.

As described previously, the door weight was set at 150 g on day 0 and increased by 100 g every 2 days to facilitate the animals' adaptation to the effort. No weight was placed on the door leading from OS to C, allowing animals to re-enter at no cost. The observation range and cutoff applied to assess the motivation for accessing the outdoor area were consistent with those used to assess the motivation for feed.

At the end of the test, the doors were removed, and the hens had free access to the outdoor space, as in the other outdoor pens.

2.6. Behavioral observation

Behavior was recorded at the pen level by video recording for one hour in the morning (from 8 am to 9 am) and one hour in the afternoon (from 3 pm to 4 pm) on all six pens (3 per experimental group). The video recording took place on Tuesday and Thursday during week 46 of age, totaling 2 days of monitoring with 2 hours of video recording per pen each day.

Before the recording, the six pens were inspected to evaluate the camera position (Action Camera) in each pen and to establish the best time of day for recordings based on the highest expressed animal activity. In each outdoor pen, the camera was located 2 m above the ground, allowing a field of view of 20 × 10 m area/camera. Behavioral observations were made by a researcher experienced in chicken behavior. The scan sampling method with sample intervals of 10 minutes was used for all 2-hour observation sessions. The number of hens per pen performing the behaviors reported in Table 1 (ethogram modified by Cartoni Mancinelli et al., 2023a) was recorded by scanning 10 consecutive seconds of video.

2.7. Animal economics

Data on the number of visits made by hens to different resources and the weight of the door they had to push during each visit were combined to determine the hens' motivational strength to access outdoor space, using feed as the gold standard. Different indices of motivational strength, including both quantity indices and rate of change indices, were calculated according to Kirkden et al. (2003) and Seaman et al. (2008):

$$Elasticity\ of\ demand = -\frac{\left(\frac{dNi}{Ni}\right)}{\left(\frac{dWi}{Wi}\right)} \quad (1)$$

It represents the change of the demand curve in relation to the price

Table 1
Description of recorded behaviors in laying hens indoor and outdoor.

	Behavior	Description
STATIC	Sitting	Chicken laying down with the underside in contact with the floor.
	Resting	Chicken standing with body parallel to the ground, head erect and eyes opened. Only the feet are in contact with the ground.
ACTIVE	Walking	Chicken moving more than three steps.
EAT	Pecking feed	Chicken pecking inside the feeder.
	Pecking grass	Chicken pecking the grass.
	Pecking floor	Chicken pecking the floor.
	Drinking	Chicken pecking inside the drinker.
COMFORT	Self-grooming	Chicken preening its own feathers.
	Wings flapping	Chicken beating its wings with breast protruding and a vertically extended posture.
	Dust bathing	Chicken forcing sand or other material into its plumage by squatting on the ground and making appropriate movements with the body, wings and legs.

(weight to push to achieve a specific resource). Values lower than 1 indicate that the demand is inelastic; the lower the value, the higher the importance of the resource for the hen.

$$\textit{Reservation price} = M(Wi) \tag{2}$$

It represents the maximum weight each hen pushed to access a specific resource; the higher the value, the greater the importance of the resource for the hen.

$$\textit{Travel cost consumer surplus} = \sum (Wi \times Ni) \tag{3}$$

It represents the cumulative effort exerted by each hen during the test to reach a specific resource; the higher the value, the greater the importance of the resource to the hen.

$$\textit{Expenditure rate} = Wi \times Ni \tag{4}$$

It represents the daily effort exerted by each hen to reach a specific resource; the higher the value, the greater the importance of the resource for the hen.

$$\textit{Relative expenditure rate} = (Wi \times Ni) \times \frac{Wi}{M(Wi)} \tag{5}$$

It represents the effort exerted by each hen relative to maximum weight it pushed to access a specific resource; the higher the value, the greater the importance of the resource for the hen.

$$\textit{Budget allocation} = \frac{\sum (Wi \times Ni)}{\sum (Wf \times Nf) + \sum (Wg \times Ng)} \times 100 \tag{6}$$

It represents the budget allocation of each hen, indicating how it distributed its effort to achieve different resources. The higher the value of a specific resource, the greater its importance to the hen.

Where:

- *Ni* denotes the number of visits (consumption) to resource *i* (feed or outdoor space) on each day of the trial.
- *Wi* denotes the door weight (price) the hen had to push to perform the visit and achieve the resource *i* on each day of the trial.
- *dNi* and *dWi* denote infinitesimal changes in number of visits and door weight.
- *M(Wi)* denotes the maximum door weight pushed by the hen (the maximum price paid) to achieve the resource *i.*
- *Nf and Wf* denote the number of visits and door weight the hen had to push to reach the feed, respectively.
- *Ng and Wg* denote the number of visits and door weight the hen had to push to reach the outdoor space, respectively.

2.8. Statistical analysis

Data were analyzed using **SAS 9.4** (Statistical Analysis System, 2013). For the motivation test, the proportion of hens passing through the door (expressed as a percentage of the present animals) to reach the resource was analyzed using PROC GLIMMIX, with door weight, resource type (feed vs. outdoor), and their interaction included as fixed effects. The hen's body weight was included as a covariate. PROC LOGISTIC was employed to estimate the predicted probability, along with 95 % confidence limits, of hens passing through the door based on a model including door weight, resource type, and their interaction as fixed effects. The indices of animal economics were analyzed with PROC GLIMMIX with resource type as a fixed effect and the hen body weight as a covariate.

Behavioral data (expressed as a percentage of animals performing a behavior in each pen per scan) were subjected to analysis of variance by using a mixed model and the PROC GLIMMIX, with housing system (indoor vs. outdoor), time of the day (morning vs. afternoon), and their interaction as fixed effects. The pen was included in the model as a random effect, allowing the consideration of the pen previously used for the motivation test in the behavioral study.

Proper data distribution (binary, normal or Poisson) was assumed after checking the distribution with PROC UNIVARIATE.

Differences among means were considered statistically significant at $P < 0.05$. The Bonferroni *t*-test was applied to compare means.

3. Results

3.1. Feed and outdoor motivation test

All nine laying hens in the motivation pen were successfully trained to use the push doors to access different areas within three days. By the end of the first week of adaptation, each hen was observed accessing different areas multiple times per day (data not shown). At the start of the testing phase, when the door weight was set to 150 g (approximately 9 % of the hens' body weight), all hens accessed both the feed and outdoor space at least once over two consecutive days (Fig. 2). The test concluded when the door weight increased to 650 g for feed (approximately 41 % of the hens' body weight) and 750 g for outdoor space (approximately 47 % of the hens' body weight), at which point only one hen accessed the resource over two consecutive days. Indeed, the proportion of hens passing through the door to achieve a resource (feed and outdoor space) declined as the weight of the door (the price the hen had to pay to achieve the resource) increased (Fig. 2A). However, the proportion of hens willing to increase their efforts to reach a resource tended to differ depending on the type of resource. Indeed, the decline in the probability of hens visiting a resource as door weight increased was more pronounced for feed than for outdoor space (Fig. 2B).

When the door weight increased, the number of visits per hen also systematically decreased ($P < 0.001$), moving from 5.72 visits at 150 g to 0.13 visits at 750 g. Moreover, a significant interaction between the door weight and the resource type was observed (Fig. 3). Specifically, the number of visits to the feed significantly decreased (from 6.94 to 2.89) with the first increase in door weight from 150 g to 250 g ($P < 0.05$). When the door weight increased from 250 to 350 g the number of visits decreased again from 2.89 to 2.13 ($P < 0.05$). Further increases in door weight led to a reduction in the number of visits per hen, although not statistically significant, ultimately reaching zero at a door weight of 750 g. The number of visits to the outdoor space also decreased with an increase in the door weight, eventually approaching zero at 750 g (Fig. 3). However, a notable interaction effect between "door weight" and "resource type" emerged, with the number of visits being higher for feed than for outdoor space at a weight of 150 g (6.94 vs. 4.50, respectively; $P < 0.05$). In contrast, an opposite trend was observed at 250 g, where the number of visits for feed and outdoor space was 2.89 and 5.94, respectively ($P < 0.05$).

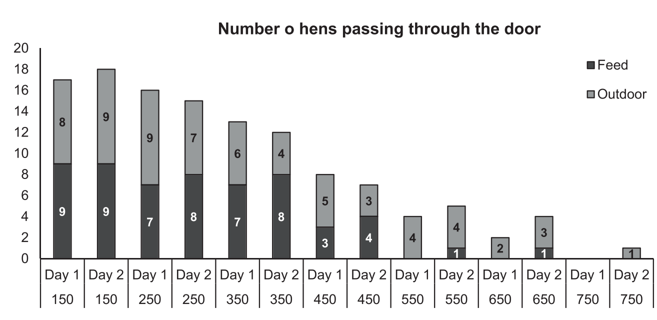

Fig. 2. Number of hens passing through the door to access feed or outdoor space.

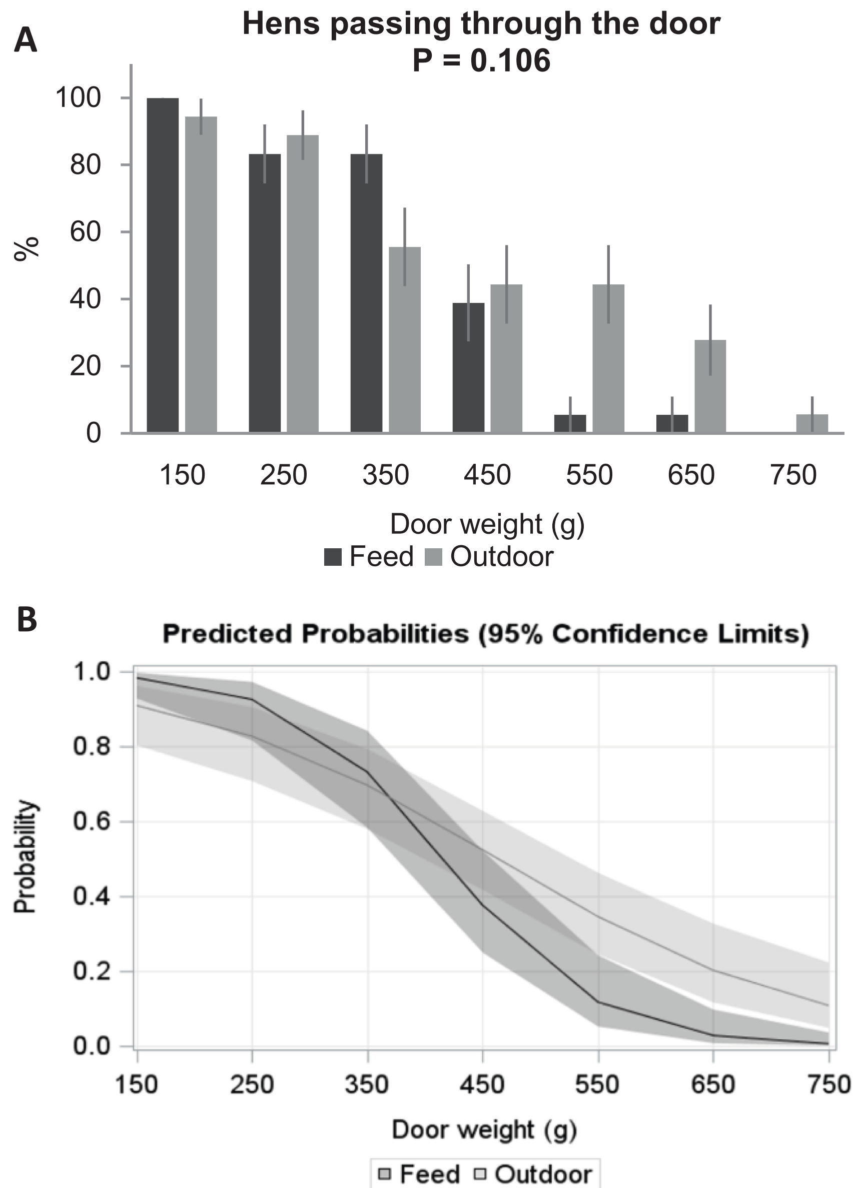

Fig. 3. Proportion of hens passing through the door (means ± standard error) to achieve feed and outdoor space according to the door weight (**A**) and predicted probabilities for the interaction "door weight × resource type" (**B**).

3.2. Economic indices to measure the motivation towards feed and outdoor space resources

As regards the analysis of animal economics, the results indicated that both the demand for feed and outdoor space resulted inelastic (<1). Specifically, the outdoor space demand was more inelastic than that for feed ($P = 0.002$; Fig. 4A), indicating that as the price (i.e., weight of the door) increases, the demand (i.e., motivation) for outdoor space decreases less than that for feed. Reservation price and total travel consumer surplus averaged 445 g and 6.881 kg, respectively, without significant differences between resources (Fig. 4B and 4C). The expenditure rate was significantly higher for outdoor space as compared to feed (+30.4 %; Fig. 4D), as well as the relative expenditure rate (+44.1 %; Fig. 4E) indicating that the animals spent their energy each day more for outdoor space than for feed. Differently, the budget allocation resulted similar between resources (Fig. 4F).

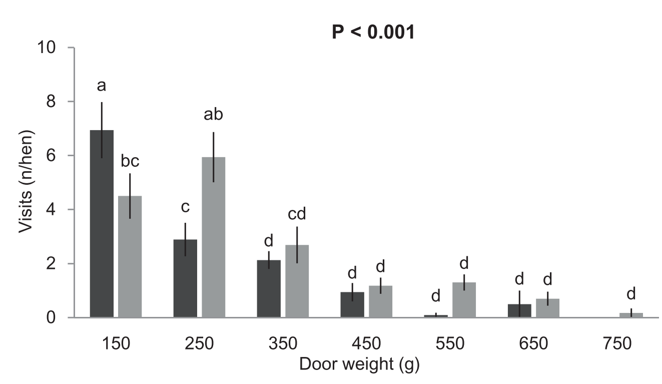

Fig. 4. Number of visits (means ± standard error) made by hens to reach feed and outdoor space. Effect of the interaction "door weight × resource type".

3.3. Behavioral repertoire in indoor and outdoor hens

Significant differences emerged from the behavioral observation of the animals, both in relation to the housing system (indoor vs. outdoor, respectively) and the time of day (Table 2). In detail, compared to indoor housing, access to outdoor space significantly decreased the percentage of hens engaged in pecking floor (-94.4 %; $P < 0.001$), resting (-32.1 %; $P < 0.001$), and other rare behaviors (-50.0 %; $P < 0.001$), while increasing the percentage of hens walking (+20.3 %; $P < 0.001$), sitting (+90.8 %; $P < 0.001$), and self-grooming (+115.0 %; $P < 0.001$). A higher percentage of hens was observed pecking feed (+53.7 %), pecking grass (+20.4 %), and sitting (+67.8 %) in the afternoon compared to the morning ($P < 0.001$). On the other hand, the percentage of hens walking was lower in the afternoon compared to the morning (-46.1 %; $P < 0.001$), as well as the percentage of hens resting (-63.5 %; $P < 0.001$) and self-grooming (-21.1 %; $P = 0.019$). A significant interaction between the "housing system" and "time of the day" effects was observed for the behaviors of walking, resting, sitting, and self-grooming (Table 2). In detail, the percentage of hens walking and resting was lower in the group indoors compared to the group outdoors in the morning, whereas in the afternoon, there were no significant differences between the housing systems ($P < 0.001$). The percentage of hens sitting averaged 12.8 % and increased significantly only in the outdoor group during the afternoon ($P < 0.001$). Finally, the percentage of hens self-grooming decreased significantly from morning to afternoon in the outdoor group, whereas the time of the day had no effect in the indoor group ($P < 0.001$) (Fig. 5).

4. Discussion

This study quantified the motivation of hens to access an outdoor space and assessed how access to such area changed their behavioral repertoire. The outdoor area covered by grass was an environmental enrichment that stimulated animals to increase the frequency of certain behaviors, such as "walking" and "self-grooming", and to expand their behavioral repertoire by expressing new ones, such as "pecking grass". The importance of expressing these behaviors was confirmed by the results of the motivational test demonstrating that the effort that animals were willing to make to access the outdoor area was greater than for other resources such as feed.

The motivational test, indeed, assessed the chickens' willingness to exert an effort to access the available outdoor area using feed as a gold standard. Feed is a well-recognized physiological need that triggers in animals a very high motivation to obtain such resource to cover their energetic costs and thus maintain homeostasis (Keramati and Gutkin, 2014). Maintaining homeostasis throughout life represents the primary challenge that an organism must face, and the requirements necessary to maintain such homeostasis can be conceptualized as "*needs*" (Prilutski and Livneh, 2023). The more complex the environment is, the more difficult it is to satisfy the different needs that the animals achieve through the engagement of complex behavior patterns (Cisek, 2022).

Results of the motivational test, as expected, showed that for both outdoor space and feed, the number of visits decreased with increasing door weight. In general, as reported in other studies about different species, the number of rewards/visits obtained declined as the cost increased (Doughty et al., 2016; Galhardo et al., 2011). However, a significant interaction effect between "door weight" and "resource type" was observed. Initially, as door weight increased, the number of visits to outdoor space decreased more than visits to feed resources. With further increases in the door weight, the number of visits to feed resources declined more rapidly than visits to outdoor space, indicating a strong preference among hens for access to the outdoor area.

In human consumer behavior, the demand curve and its elasticity are used to assess how changes in price affect the consumption of a particular resource. Our study is defined as an operant test because we applied increasing costs, represented by the door weight, to access the resources. This setup allowed us to calculate the demand elasticity for both outdoor space and feed resources.

However, this measurement is criticized by several authors because it did not consider the effect of the satiation of a determinate resource (Kirkden et al., 2003; Kirkden and Pajor, 2006) or that a certain resource could be influenced by the subject's budget time, increasing demand elasticity (Warburton and Mason, 2003; Sørensen et al., 2004). Indeed, to correctly measure the demand elasticity, a fixed relation between the unit of cost paid and the unit of reward delivered is necessary (Gunnarsson et al., 2000). In our setup, measuring the quantity of feed or grass (the primary resource available in the outdoor space) consumed during each session could interfere with the animals' behavior. Therefore, unlike in human studies, where quantity is often used, we used the number of visits each animal made to each resource as a measure of reward relative to the door weight (cost paid by animals).

Results showed that both resources were characterized by an inelastic demand (<1.0) which means that changes in price have little effect on the quantity demanded (Kirkden et al., 2003) and that both resources are considered necessary for animals. The inelastic demand exhibited by both resources under study also suggests that we chose two comparable rewards, making them useful in providing information about the real animal's motivation towards one of them. In this context, the lower elasticity observed for outdoor space compared to that for feed underscores that animals were willing to continue paying to go outside even when the effort to access the outdoors increased. Conversely, they were more sensitive to changes in effort required to access feed, and even moderate additional efforts reduced demand. This finding highlights the importance of providing laying hens with access to outdoor space and enriched environments. This also confirms that such conditions represent the reference point for gathering valuable information on how hens behave when they are in a positive affective state.

Another drawback of demand elasticity, especially in a setup like

Table 2
Effect of the housing system and time of the day on the behaviors of laying hens (expressed as % of the present animals). Data are reported as means ± standard error.

Housing system (H)	Indoor		Outdoor		P-value		
Time (T)	Morning	Afternoon	Morning	Afternoon	H	T	H×T
Pecking feed	28.7 ± 2.4	44.1 ± 3.3	0.00 ± 0.0	0.00 ± 0.0	n.e.	<0.001	n.e.
Pecking grass	0.00 ± 0.00	0.00 ± 0.0	26.9 ± 3.1	32.4 ± 3.9	n.e.	<0.001	n.e.
Pecking floor	4.94 ± 1.29	6.17 ± 1.62	0.62 ± 0.43	0.00 ± 0.00	<0.001	0.282	0.971
Drinking	3.09 ± 1.44	2.78 ± 1.12	0.00 ± 0.00	0.00 ± 0.00	n.e.	0.446	n.e.
Walking	22.2[b] ± 2.3	14.2[c] ± 2.0	29.9[a] ± 2.7	13.9[c] ± 2.2	0.001	<0.001	<0.001
Resting	22.8[a] ± 2.6	6.79[c] ± 1.84	13.6[b] ± 2.0	6.48[c] ± 1.36	<0.001	<0.001	<0.001
Sitting	9.57[b] ± 2.13	8.02[b] ± 1.96	9.57[b] ± 1.99	24.1[a] ± 3.4	<0.001	<0.001	<0.001
Self-grooming	6.48[c] ± 1.56	7.72[c] ± 1.87	18.5[a] ± 2.3	12.0[b] ± 1.9	<0.001	0.019	<0.001
Dust bathing	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	10.8 ± 2.7	n.e.	n.e.	n.e.
Wings flapping	1.60 ± 0.90	8.64 ± 1.48	0.60 ± 0.43	0.00 ± 0.00	0.965	0.975	0.968
Other	0.62 ± 0.43	0.62 ± 0.43	0.31 ± 0.31	0.31 ± 0.31	0.009	0.999	0.999

[a, b, c] Different superscript letters indicate significant differences among means ($P < 0.05$).
n.e. = Not estimable.

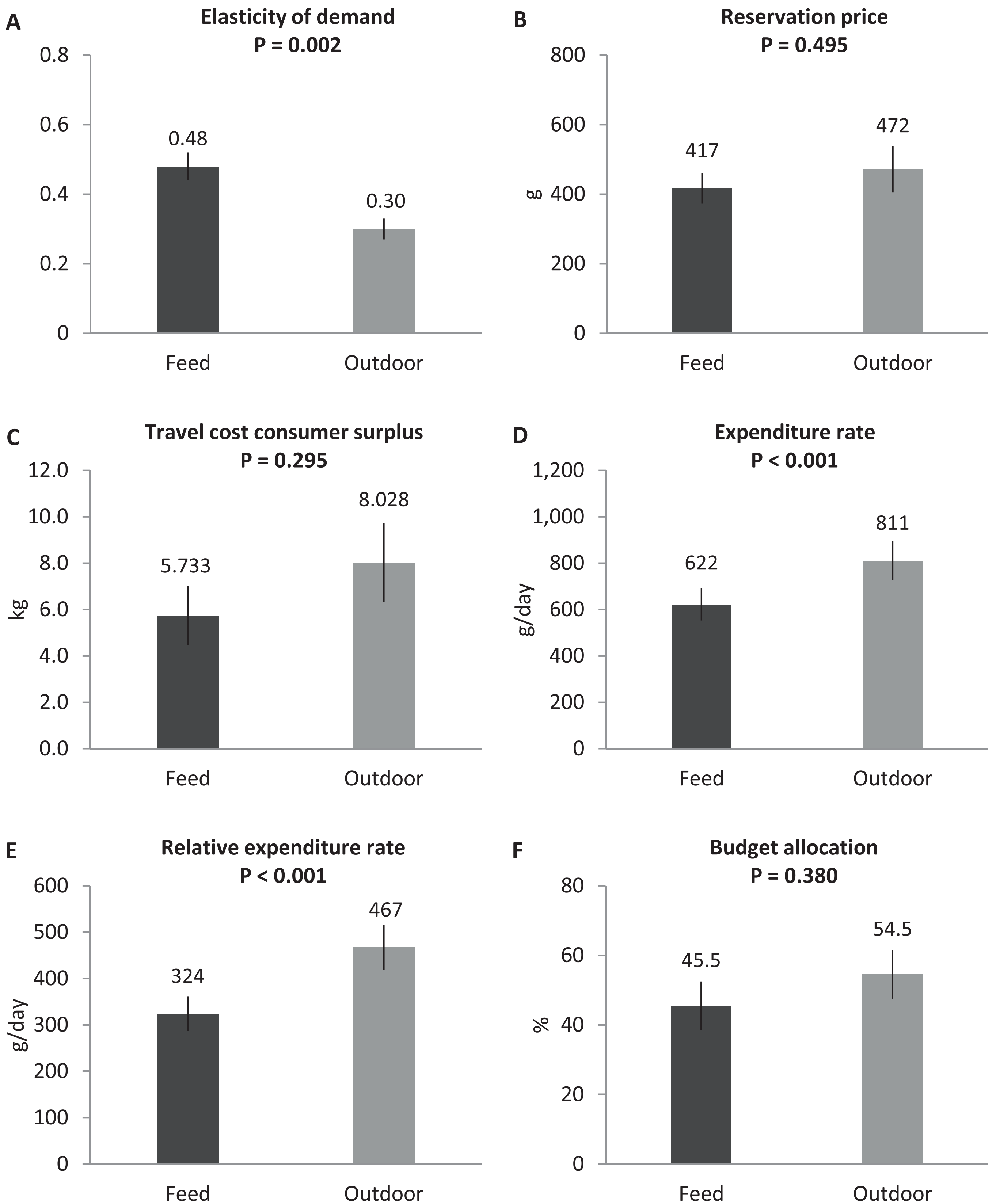

Fig. 5. Elasticity of demand (**A**), reservation price (**B**), travel cost consumer surplus (**C**), expenditure rate (**D**), relative expenditure rate (**E**) and budget allocation (**F**) of hens for feed and outdoor space.

ours with an increasing cost to pay, is when the price per reward has become too high, and the animals stop working to reach the resource. In fact, it is rare that all the tested animals interrupted their work from one section to the next. Thus, if the level of requests decreases after a certain cost or exhibits a fluctuating trend, this could increase the demand elasticity (Jensen et al., 2008). To address this aspect, a criterion working at the individual level was applied to close the motivational tests. The tests were interrupted for each individual when they did not cross the door for two consecutive sessions (days). The price when this occurs is defined as the maximum price paid, or the reservation price (Hansen and Jensen, 2006).

In this study, the trend of the reservation price suggested that hens were willing to pay a higher cost to access the outdoor space than the feed one. Moreover, even though not all the economic parameters used in our study to assess the resource value exhibited significant differences between feed and outdoor space, they showed similar trends highlighting the hens' motivation towards outdoor space. The expenditure rate and the relative expenditure rate parameters, in fact, confirm the results of demand elasticity. By combining, for each resource, the number of visits with the related weight of the door, and these two factors with the maximum weight pushed respectively, they showed that the rate of expenditure for feed was lower than that for outdoor space.

In our study, all hens involved in the trial were able to face an operant task and were willing to work for a reinforcer. Indeed, pushing the door is an acceptable and easy work for hens, which probably recalls actions that these animals are used to doing in their natural environment (e.g., moving obstacles to reach resources). This represents an important indication for further motivational studies where the same apparatus could be used.

To our knowledge, this is the first study that applied an operant test to evaluate hens' motivation for outdoor space. Thus, it is difficult to compare our results with those of other studies. However, some considerations are possible thanks to the behavioral observations recorded during the trial. In the outdoors, the frequency of several behaviors increased (i.e., walking, sitting, and grooming), and the animals could express new ones, such as pecking grass and dust bathing. Thanks to the motivational test, we now know that hens are willing to pay a high price for them, higher than that paid for feed. Therefore, these behaviors, not exclusively aimed at satisfying energetic costs, may be considered *needs.* It is difficult, however, to distinguish which specific behaviors drove their motivation for the outdoor area, and only a few hypotheses can be made.

The behavior repertoire expressed by the hens in the outdoor area was wider, as also previously shown (Jacobs et al., 2023; Cartoni Mancinelli et al., 2019). Clearly, under our conditions, access to outdoor area with increased space allowance and the presence of other valuable resources such as suitable substrates for dust bathing, allowed hens to engage in kinetic activity and increased comfort behaviors. Dixon et al. (2014) tested the motivation of broilers for exploratory and foraging behaviors. They used an apparatus in which birds could cross a water runway to access a wooden platform where they could perform exploratory and foraging behaviors, but they were not rewarded with feed. Results showed that broilers were willing to work for the opportunity to forage even though the food was never provided, suggesting that the motivation was driven by the appetitive component of feeding behavior (not only by the consummatory phase results in ingestion). In our study, approximately 30 % of outdoor hens were observed pecking grass, thus suggesting that the need for this specific resource was an important driver of their motivation to access outdoor space. Moreover, the "pecking floor" behavior decreased in outdoor hens compared to the indoor ones. Pecking other things, identified in our study as "pecking floor", is considered a behavioral part of food searching and, consequently, it is strictly related to foraging behavior (Dixon et al., 2014). The lowest frequency of "pecking floor" in outdoor hens could suggest that the grass presence satisfied the food searching and that this appetitive behavior could be partially substituted with the "pecking grass" behavior.

The outdoor space stimulates animals to perform other behaviors, such as "dust bathing", which was not shown by indoor birds. Dust bathing is a "high-priority behavior" (European Food Safety Authority EFSA, 2005) and is classified as a comfort behavior of hens (Welfare Quality, 2009). Similarly, "self-grooming" and "wings flapping" belong to the comfort category. The former showed a higher frequency in the outdoor systems than in the indoor ones, whereas the latter was expressed more in indoor hens. This is likely because "self-grooming" is closely related to the "dust bathing" behavior (Sandilands, 2001), as it helps hens to remove the excessive substrate kept in their feathers. In indoor hens, the frequency of this behavior was likely so low due to the lack of an adequate substrate for dust bathing, as previously observed in hens with access to wood shavings, straw, or plastic turf mats (Campbell et al., 2017). Therefore, this behavior was not detected through the scan sampling adopted in the study (Cartoni Mancinelli et al., 2023b). However, "wings flapping" was the most frequently observed comfort behavior among indoor birds. In our study, the manifestation of comfort behaviors in both housing systems suggests that the motivation of hens towards the outdoor area was not triggered by poor indoor conditions, but it is probably linked to a high interest in the resources provided by the outdoor space, including alternative substrates (potting soil powder), grass, natural light, and fresh air that can enhance behavioral expression and overall welfare. Indeed, a recent study has reported that hens with outdoor access exhibit increased foraging and dust bathing behaviors (Campbell et al., 2022). Furthermore, natural daylight exposure has been linked to improved health outcomes in poultry, including better feather conditions and reduced stress levels (Xu et al., 2022).

5. Conclusions

To the best of our knowledge, this is the first study where an operant test to assess the hens' motivation towards outdoor space was applied. All hens involved in the study were able to push a weighted door, underlining that this methodology could be used in other motivational tests. The significant economic indicators suggest that hens exhibited greater motivation for outdoor space than for feed, and they could numerically quantify the strength of motivation. The behavioral observations, as expected, showed that the outdoor hens expressed an enlarged behavioral repertoire with respect to the indoor ones. However, in both housing systems, animals displayed comfort behaviors like wings flapping, suggesting that the hens' high motivation towards the outdoor area was not linked to uncomfortable conditions in the indoor area, nor simply to a need for higher space allowance. Motivated behaviors such as "dust bathing" could justify the higher price paid for access to the outdoor area. However, the frequency of self-grooming and walking behaviors also increased in the outdoor hens, which even replaced pecking on the floor with grazing. Thus, it is not easy to distinguish which behavior mainly drives their high motivation. To identify these drivers, future studies should compare different environmental conditions in outdoor spaces and use longer video recordings to better evaluate behaviors that, although less frequent and of short duration, can be associated with a positive affective state.

Authors' contributions

ACM, MB, and DC conceptualized the study. ACM, DC and SM organized the trials and collected experimental data. MB performed the statistical analysis. ACM and MB interpreted the data and wrote the first draft of the manuscript. CC and MB provided funding for the study. All authors critically reviewed the manuscript for intellectual content and gave final approval of the version to be published.

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CRediT authorship contribution statement

Chiattelli Diletta: Writing – review & editing, Investigation, Conceptualization. **Cartoni Mancinelli Alice:** Writing – review & editing, Writing – original draft, Validation, Investigation, Data curation, Conceptualization. **Birolo Marco:** Writing – review & editing, Writing – original draft, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Castellini Cesare:** Writing – review & editing, Funding acquisition. **Mariotti Sara:** Writing – review & editing, Investigation. **Menchetti Laura:** Writing – review & editing.

Declaration of Competing Interest

The authors have no conflicts of interest to disclose.

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