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An Evaluation of the Uses of Different Environmental Enrichments on a Broiler Farm with the Help of Real-Time Monitoring via a Farmer-Assistant System

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Abstract: Modern broilers are usually raised in barren environments in large enclosed halls. Various environmental enrichment elements such as perches, elevated platforms, and similar structures were proposed for these barns with the aim of improving the welfare and well-being of the birds. This study compares and evaluates three different types of environmental enrichment. In 2 identical barns, 8100 Ross 308 broilers were housed divided between a control group (CG) and a trial group (TG). In the TG, three types of environmental enrichment (perches, elevated platforms, and a combined structure) were used. A real-time monitoring device (FAS = farmer-assistance system) suspended from the ceiling was used in combination with single photographs to count the number of birds on the enrichment elements. In addition, the body weights of individual birds and their foot pad dermatitis (FPD) scores were collected at days 14, 21 and 28 in both barns. No differences in these parameters were seen between TG and CG. Birds showed highest preference for the elevated platforms (average 31.93 kg/m^2), followed by the combined structure (average 21.36 kg/m^2) and the perches (0.35 kg/m^2). Overall, this study shows that Ross 308 broiler birds significantly prefer elevated platforms over combined structures or simple perches.

Keywords: broiler; enrichment; animal welfare; performance; real-time monitoring

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1. Introduction

Broiler meat is the fastest growing sector of food derived from animals [1]. The birds are usually kept indoors in large barns offering only a few structuring elements above ground level for the animals [2,3]. This barren environment can lead to boredom, inactivity, distress, and behavioural- and even health-related disorders [4,5]. In order to avoid or mitigate these negative consequences of such a barren environment, a variety of environmental enrichment elements were tested. The provision of elements such as perches, elevated platforms, and similar structures was postulated for broiler production to improve the welfare and quality of life of these broilers [6]. Providing environmental enrichment can target problems with inactivity by offering incentives, for example, to climb elevated places, while also allowing the birds more flexibility in exhibiting a wider range of specific behaviours [7].

In particular, concerns regarding animal welfare have recently arisen [8]. This development has also brought new challenges: To improve animal welfare, the problems relating to the current forms of husbandry must first be addressed in order to then find, test, and evaluate solutions and improvements. One problem is the structure of the barns, or rather, the lack of structure [6]. On most commercial broiler farms, birds are raised on a flat concrete floor covered with wood shavings [2], and the housing offers no structural elements above the ground level other than the feeding and drinking lines [3]. In combination with high stocking densities, this lack of structuring elements can lead to common production diseases such as foot pad dermatitis (FPD) [9], deep skin dermatitis, and sudden cardiac death [10]. These diseases, also termed cumulative disorders or technopathies, can heavily impair the welfare of the animals [11].

A promising approach is environmental enrichment elements that allow the animals to exhibit more natural behaviours. The term environmental enrichment has been defined by Newberry as "an improvement in the biological functioning of captive animals resulting from modifications to their environment" [12].

In recent years, many different types of environmental enrichment have been tested [13–16]. Most approaches deal with enabling natural behaviours such as pecking, hooting, or seeking elevated perching positions. Others dealt with, for example, the type of feeding [17] or more intensive human care [18]. One important aspect of the natural behaviour of broilers is seeking elevated positions to rest. Day-old broilers develop the urge to seek hiding places and elevated positions as they grow older as it is part of their species-specific behaviour [19]. As a kind of protection mechanism against potential predators, chickens took up elevated positions in the wild [20,21]. This could be the reason why birds have been shown to be eager to take up elevated seating positions and even make an effort to climb up to them [21–23]. In this way, the provision of environmental enrichment elements can help to encourage natural behaviour in birds while also giving them a more secure feeling [24].

Several options for enrichment in the form of elevated structures that offer seating possibility like straw bales [25], perches, and small elevated floors [23,26] have been the focus of research in recent years, for example the elevated plastic platforms 30 cm above the ground accessible via ramps with an angle of 15° used by Kaukonen et al. [27], the galvanized steel pipes 15 cm above the ground used by Aksit et al. [28], or the wooden beams 10 cm above the ground used by Ventura et al. [26]. This is driven by the awareness in society of the importance of animal welfare. Animal numbers per m^2 and stocking densities in general [8] should be reduced and the animals should be offered more opportunities to perform their natural behaviours. Therefore, it is necessary to investigate and evaluate environmental enrichment elements which are offered by industry in regard to broiler health and welfare [4,14].

When testing and evaluating the use of the structures by the birds, digitalisation and modern monitoring devices can be of value especially when assessing the elements in commercial farms [29]. A considerable advantage digitalisation offers is "real-time" monitoring. Data and pictures of animals can be collected even when no farmer is present [30]. The continuous collection of data offers the possibilities to have a look at how the birds interact with the environmental enrichment over the course of 24 h a day. The air conditions in the barn have a significant influence on broiler health [31] and welfare. Knowing the air conditions in the barn together with continuous monitoring of the birds can possibly help to detect healt and welfare problems earlier than usually recognized by the farmer or when they happen at nighttime.

The aim of this field study was to investigate and evaluate the use of elevated platforms, perches and a combination of both which are offered as typical enrichment elements for broiler houses. Research regarding these points is important as there is a lot of potential for environmental enrichment to improve animal health and welfare. The acceptance of the structures by the broilers and their influence on broiler behaviour were analysed by personal observations. In addition, photos of all elements and the birds on them were regularly taken and evaluated to be able to describe how the birds react to the different types of enrichment and to see whether it has an influence on the distribution of the birds on the floor in the barn. The results were compared with the control group without environmental enrichment elements.

2. Materials and Methods

2.1. Animals and Diets

2.1.1. Animals

In this trial, for each of the 8 rounds, 8100 broilers were housed per group. They were randomly distributed between the control group and trial group as hatched. Over the course of 9 fattening rounds, this resulted in a total of 72,900 birds. The genetic strain used was Ross 308.

2.1.2. Diets

The birds were fed pellets ad libitum in four phases (Table 1). The feed was provided by a commercial feed supplier (MEGA Tierernährung GmbH & Co. KG, Visbek, Germany). From the day of arrival to d 7, the birds were fed a starter diet which was afterwards replaced by a grower one diet. At d 20, the birds were fed a grower two diet. Ultimately, at d 29, the birds were fed a finisher diet up until 12 h before departure to slaughter at d 33.

Table 1. Composition of the commercial diets used for control and trial groups.

Ingredients (in %)	Starter	Grower One	Grower Two	Finisher
Crude protein	21.60	19.00	19.00	19.50
Ether extract	5.40	4.70	4.70	7.80
Crude fibre	2.50	3.50	3.20	3.20
Crude ash	5.50	5.40	5.10	4.80
Calcium	0.90	0.75	0.70	0.65
Phosphorus	0.85	0.55	0.50	0.40
Sodium	0.16	0.16	0.15	0.14
Lysine	1.35	1.12	1.12	1.14
Methionine	0.80	0.28	0.54	0.28

2.2. Experimental Design and Housing

The experimental and the control barns had identical sizes, equipment, and management. The rectangular floor space was 16 m by 30 m. The length of the fattening period was 33 days.

The barns were equipped with three conventional feeding lines (Big Dutchman International GmbH, Vechta, Germany) and four conventional water lines (LUBING Maschinenfabrik Ludwig Bening GmbH & Co. KG, Barnstorf, Germany) with drinking nipples (LUBING Maschinenfabrik Ludwig Bening GmbH & Co. KG, Barnstorf, Germany), as shown in Figures 1 and 2. Both barns were evenly littered with wood shavings (GOLDSPAN®, Goldspan GmbH and Co. KG, Goldenstedt, Germany). Figure 2 in addition shows the enrichment elements.

At d 0, the light programme was 24 h of light. At d 1, the light was turned off for 4 h between 23:00 and 03:00. At d 2, the 6-h dark period occurred between 22:00 and 04:00. Starting at d 3, the light was turned off for 8 h from 21:00 to 05:00. From d 21 onwards, the dark period was shortened to 6 h between 22:00 and 04:00.

At the arrival of the birds at d 1, the air in the barn was heated up to 33.5 °C with a gas air-heating system. The air temperature was then continuously lowered until it reached 23 °C at d 33. To control the negative pressure ventilation system and the air quality, the air was measured with temperature and humidity sensors.

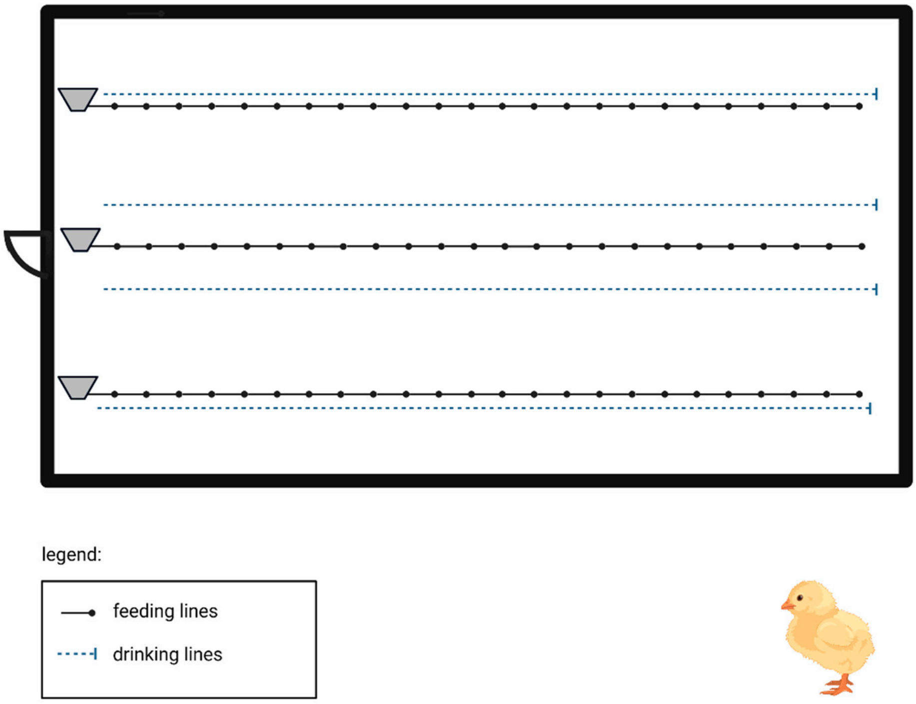

Figure 1. Schematic drawing of the control groups (figure was created with Biorender.com (accessed on 7 October 2022)).

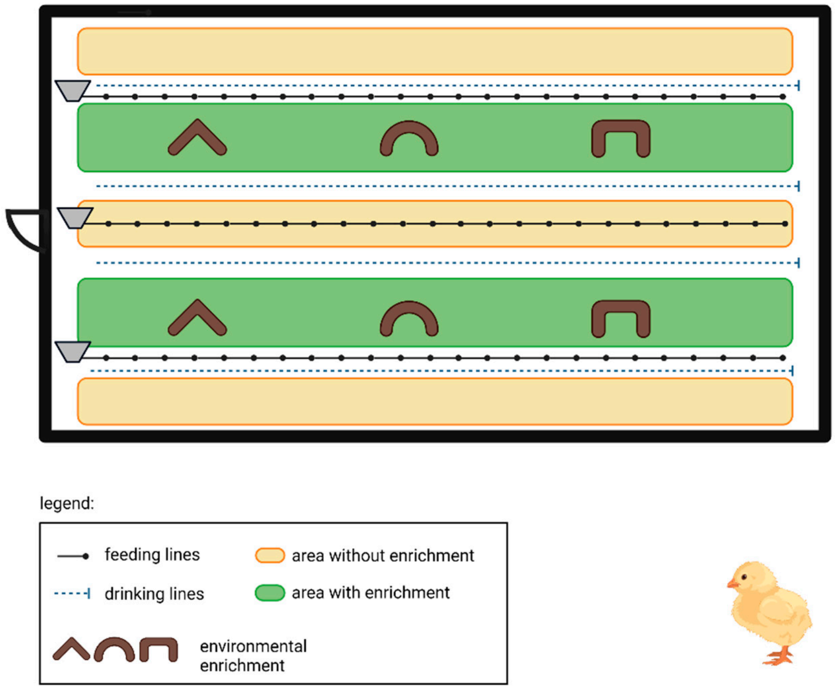

Figure 2. Schematic drawing of the trial groups (figure was created with https://biorender.com/ (accessed on 7 October 2022)).

At d 12, the birds were vaccinated against Newcastle disease; at d 18, against Gumboro; and at d 20 against infectious bronchitis with virus strain Ma5 with conventional vaccines in the recommended dose via the drinking water.

2.3. *Experimental Treats*

2.3.1. Environmental Enrichment

During the trial, three different elements of environmental enrichment were used (Figures 3–5): The first element was perches. The enrichment used for evaluating perches was the so-called "A-Reuter", which was originally made for keeping broiler parent stock. The construction had a length of 5.60 m and was 1.40 m wide. The A-Reuter consisted of 5 metal perches that were equal in length and had a diameter of 1.90 cm each. All perches were mounted on a frame made of the same material.

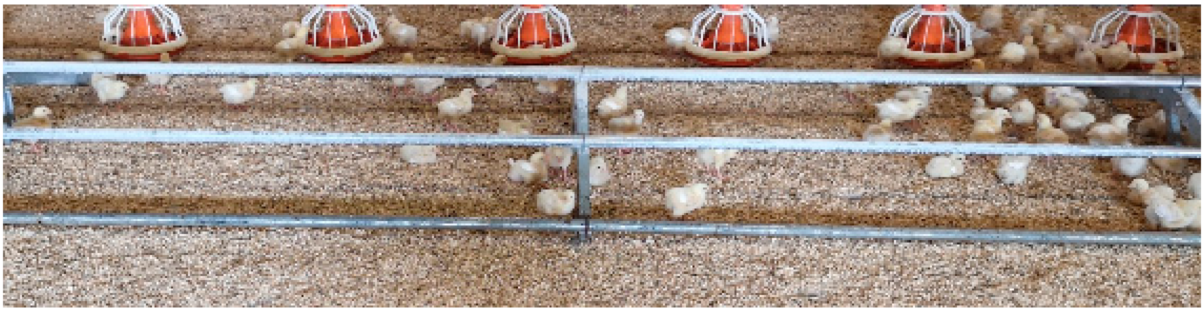

Figure 3. Photograph of the perch variant of environmental enrichment, "A-Reuter".

Figure 4. Photograph of the elevated platform variant of environmental enrichment, the "Plateau".

Figure 5. Photograph of the combined variant of environmental enrichment: the "Hybrid".

The second element was elevated platforms. The enrichment used as an elevated platform was the so-called Plateau. This consisted of two carriage axles with two tyres each. A rectangular framework was mounted on top of the axles. This framework held the grids, each of which measured 1.20 m long and 0.75 m wide, making the whole Plateau 2.40 m long. On both of the long sides, a ramp consisting of one of those grids was mounted to allow the birds access to the top.

The third category is a combination of perches and elevated plains. For the combination we used the Hybrid (Hölscher + Leuschner GmbH & Co. Kg, Emsbüren, Germany). It is composed of three perches, which are attached at right angles to two elevated plains. Both elevated planes are accessible via two ramps each. The elevated plains are 248 mm wide and 1012 mm long. In-between the planes there are two perches of 1.5 m length. Two of those are mounted underneath the elevated planes. This leaves a space of 992 mm between the inner sides of the elevated planes. Four elements of the Hybrid additionally had a third perch above the planes which is mounted on a rectangular frame. Each perch is 52 mm wide and 78 mm high, with a rounded top part for the birds to sit.

All three environmental enrichments described above, A-Reuter, Plateau, and Hybrid, were used in each of the experimental runs with enrichment. In order to exclude any influence of their position in the barn, their positions were changed from trial to trial in rotation in a clockwise direction. This meant that an environmental enrichment element that was placed at position one, which is located at the front of the trial barn, at the outset of the trial was placed in the following round of trial at position two located in the middle of the trial barn and thereafter at position three at the back of the trial barn.

2.3.2. Farmer-Assistant System

The Farmer-Assistant System (FAS) is a livestock robot that consists of an upper and a lower box connected by a telescopic arm. The upper part contains the battery, the motor, the drive wheels, and the upper camera. This camera provides an overview of the barn. The robot runs on a railway that is located underneath the roof of the barn. The railway enables the FAS to run the sensor box at a height of 70 cm above the broilers without disturbing them, while constantly monitoring the climatic conditions and the flock. The sensors for this are located in the lower box. They continuously measure air temperature, relative humidity of the air, wind speed, carbon dioxide (CO_2), ammonia (NH_3), light, and noise. The lower box also contains a bottom camera and two side cameras in order to be able to observe the broilers more precisely. The collected data are presented to the farmer in a daily report every morning. A cloud-based system stores the raw data for all parameters in a raw form but also in figures mapped over a virtual version of the barn floor. The parameter-free space is calculated through an algorithm. The top camera takes an image, and the artificial intelligence of the robot detects the birds present in that image. The amount of free space is then calculated from the area of the floor minus the space that birds take up on the given image.

2.4. Measurements

2.4.1. Growth Performance and Slaughter Data

First, 50 birds were randomly selected, and their weight was measured at d 14, 21, and 28 of life over the course of all rounds of trial (Figure 6). A hanging scale (VEIT Electronics s.r.o., Moravany, the Czech Republic) was used to record the birds' weight. The total weight and the number of birds were measured at the slaughterhouse and the average body weight was then calculated therefrom. The slaughterhouse used a camera-based system common in Germany and according to the common FPD scoring (QS Qualität und Sicherheit GmbH, Bonn, Germany) at slaughter. The scores of this scoring system are defined as 0, 1, 2a and 2b [32] and are afterwards calculated into a number for footpad points.

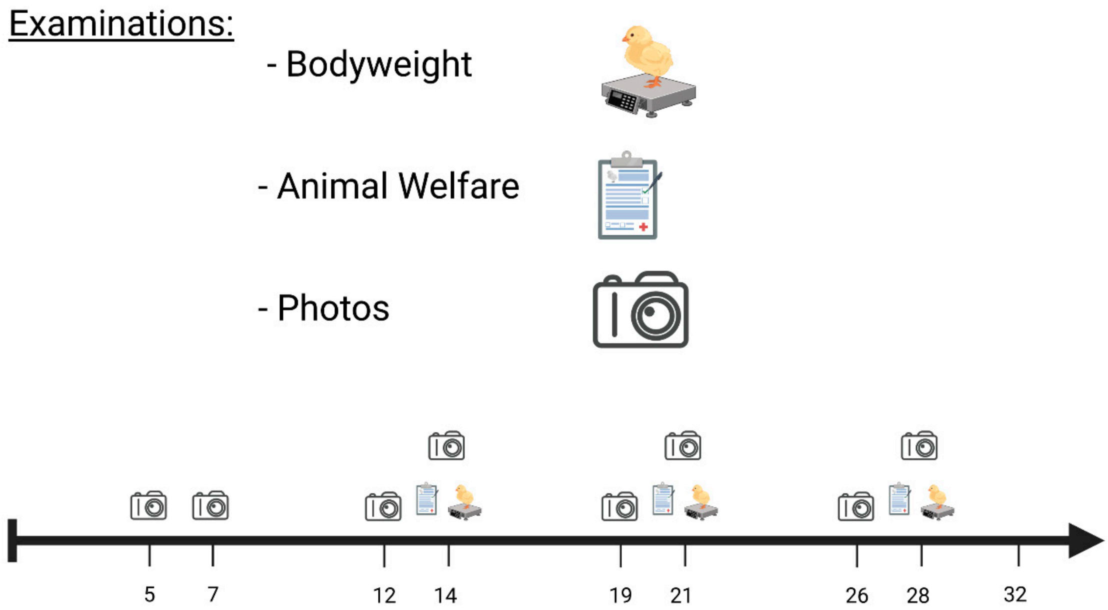

Figure 6. Timeline of examinations made and photographs taken during one trial round (figure was created with https://biorender.com/ (accessed on 7 October 2022)).

2.4.2. Photographs and Evaluation

As described in Figure 6, photographs were taken at d 5, 7, 12, 14, 19, 21, 26, and 28. Each type of environmental enrichment was photographed separately over the course of three trial rounds. Under the roof of the barn, the photos were taken from a windowed corridor so that the animals would not be startled or otherwise affected by the picture taking. To ensure that each image showed the same section of the image, markings were placed on the windows for the individual enrichments to indicate the points for the images. As the positions of the environmental enrichments were rotated each run, the alignment of the individual elements in the barn had to be checked once at the beginning of each run to match the markers. The number of birds per square metre was calculated by dividing the total number of birds on top of one element of environmental enrichment by the size of the element. The size of each element was calculated by multiplying the length of it with its width. The kg per square metre was then calculated by multiplying that value with the average weight of birds on the actual day. Afterwards the difference from the average weight in the barn was calculated by subtracting the value for kg per square metre from the average weight in the barn.

2.4.3. Feed Conversion Ratio

By dividing the feed intake (kg) by the total BW (kg) of all birds, the feed conversation ratio (FCR) could be calculated. This was calculated for all fattening rounds in the control group and trial group. To have a slightly more precise value, it is possible to calculate the corrected FCR, which also takes bird losses into consideration. At first, the cumulative feed intake of the dead animals needs to be calculated. This is the sum of the daily feed intakes of each animal up to the day of departure. Then the corrected feed intake in kg needs to be calculated. The corrected feed intake is obtained by subtracting the cumulative feed intake of the dead animals from the total feed intake. Then the corrected feed intake is divided by the total body weight gain in order to obtain the corrected FCR.

2.4.4. Foot Pad Dermatitis

As an indicator of animal welfare and to control whether the environmental enrichment has an influence on the foot pads, the FPD scores were taken in all of the nine fattening runs. For this purpose, 50 animals were randomly selected from the flock on each of the examination days. The FPD scores of these animals were then recorded, looking at the central plantar area on both feet of these 50 broilers at d 14, 21, and 28 (Figure 6). A seven-point scale according to Mayne et al. [33] was used to evaluate the FPD scores. As described in Figure 7, the first score on this scale is 0, which means the feet show no external signs of FPD. Score 3 marks the point where the central part of the footpad is swollen, red, and hard and where the first necrotic areas are visible. In increasing order, a larger size of the necrotic areas is then described until ultimately Score 7 describes a foot pad where half of the central plantar area is covered in necrotic scales.

Score	Description of footpad
0	No external signs of FPD are visible. Skin of the footpad and digital pads appears normal, no redness, swelling or necrosis is evident. The skin of the footpad feels soft to the touch.
1	Slight swelling and/or redness of the skin of the footpad.
2	The pad feels harder and denser than a non-affected foot. The central part of the pad is raised with swelling and redness and the reticulate scales may be separated. The digital pads may show similar signs.
3	The central and digital footpads are enlarged and swollen with red areas, and as the skin has become compacted, the footpad is hard. The reticulate scales have become enlarged and separated, and small black necrotic areas may occur.
4	Marked swelling and redness around the margins of lesions occur. Reticulate scales die and turn black, forming scale-shaped necrotic areas. The scales around the outside of the black areas may have turned white. The area of necrosis is less than one-eighth of the total area of the footpad.
5	Swelling and redness are evident in the central and digital footpads. The total footpad size is enlarged. Reticulate scales are pronounced, increased in number, and separated from each other. The amount of necrosis extends to a quarter of the footpad. Small necrotic areas may also appear on the digital pads.
6	As score 5, but with half the footpad covered by necrotic cells. The digital pads may have up to half of one pad covered with necrotic cells.
7	A footpad with over half of the footpad covered in necrotic scales.

Figure 7. Foot pad scoring according to Mayne et al. (2007) [33].

2.5. Statistical Analysis

Data analysis was performed using the SAS statistical software package, version 7.1 (SAS Institute, Cary, NC, USA). First a Shapiro–Wilk test for normal distribution was performed. All measurement data were analysed descriptively according to sample size, means, confidence interval, standard deviation, minimum and maximum. For data not normally distributed, a Kruskal–Wallis test was performed, followed by a Wilcoxon two-sample test. Normally distributed data were checked for significant differences with the Ryan–Einot–Gabriel–Welsch-test (one-way ANOVA). The analysis of the values for foot pad scoring was performed using a Kruskal–Wallis test. All statements of statistical significance were based on $p < 0.05$.

3. Results

3.1. Growth Performance and Slaughter Data

3.1.1. Growth Performance

Table 2 displays and statistically compares the average BW for d 14, 21, and 28. The BWs were collected from 50 individual broilers from both control and trial.

Table 2. Average body weight (g) ± standard deviation of individually weighed birds from day 14 to 28 of life in both the control (CG) and trial group (TG).

Day of Life	n	CG	TG	*p*-Value
14	50	524.23 ± 60.94	525.41 ± 52.23	0.7543
21	50	1045.04 ± 124.86	1034.96 ± 128.41	0.2328
28	50	1675.44 ± 197.54	1699.90 ± 186.33	0.0563

As shown in Table 2, no significant differences in average BW were seen between the control and the trial group at d 14, 21, and 28 of life.

3.1.2. Footpad Scores

Table 3 shows the average foot pad disease scores at d 14, 21 and 28 for both trial group and control group.

Table 3. Foot pad disease score ± standard deviation, in accordance with Mayne, scored for both feet of 50 birds per day in the control (CG) and the trial groups (TG).

		CG	TG	*p*-Value
Day of Life	n	FPD Score	FPD Score	
14	450	0.88 ^{b} ± 1.15	0.65 ^{a} ± 0.99	0.0019
21	450	1.64 ^{b} ± 1.72	1.12 ^{a} ± 1.48	<0.0001
28	450	1.79 ^{a} ± 1.94	1.75 ^{a} ± 2.13	0.1836

a, b Means in a row with different superscripts differ significantly ($p < 0.05$).

Table 3 shows significant differences for day 14 and 21 between control and trial group, when the scores in the trial group were significantly lower.

3.1.3. Slaughter Data

The slaughter data were reported after each single round of trial directly from the slaughterhouse. Table 4 displays the average BW and the foot pad scores scored at the slaughterhouse with standard deviation for the control and the trial group at d 33.

Table 4. Slaughter data regarding average body weight (g) ± standard deviation per bird and foot pad points ± standard deviation according to QS Qualität und Sicherheit GmbH, Bonn, Germany, for the control (CG) and trial group (TG) over nine trial rounds.

	CG n = 67,780	TG n = 69,609	*p*-Value
Bodyweight (g)	2059.89 ± 66.66.	2048.44 ± 48.70	0.6830
Foot pad score	12.00 ± 12.47	15.55 ± 10.85	0.5281

As Table 4 displays there were no significant differences between the control and trial group.

3.1.4. Feed Conversion Ratio

The FCR and the corrected FCR are displayed and analysed for the control and trial groups in Table 5.

Table 5. Feed conversion ratio (kg feed/kg body weight gained) and corrected feed conversion ratio (corr. FCR) ± standard deviation in the control (CG) and trial group (TG) over nine trial rounds.

	N	CG	TG	*p*-Value
FCR	9	1.43 ± 0.02	1.41 ± 0.02	0.2060
corr. FCR	9	1.42 ± 0.03	1.41 ± 0.02	0.3279

Table 5 displays no significant differences between the control group and the trial group regarding FCR and corrected FCR.

3.2. Photo Evaluation

3.2.1. Birds on Environmental Enrichment

Table 6 shows the total number of birds observed at the time of each taken photograph for each different type of environmental enrichment.

Table 6. Average total number of birds on the different types of environmental enrichment over the course of three rounds of trial ± standard deviation in the trial groups (TG) at the time of taking photographs.

	Week 1	Week 2	Week 3	Week 4	*p*-Value
"A-Reuter"	1.00 ^{a} ± 0.63	1.83 ^{a} ± 1.47	1.33 ^{a} ± 0.82	2.17 ^{a} ± 0.75	0.2000
"Plateau"	67.50 ^{c} ± 10.86	65.83 ^{c} ± 8.66	68.17 ^{c} ± 5.23	68.67 ^{c} ± 8.19	0.9427
"Hybrid"	49.00 ^{bB} ± 9.78	47.58 ^{bB} ± 5.85	40.92 ^{bA} ± 3.15	38.33 ^{bA} ± 4.46	0.0002
p-Value	<0.0001	<0.0001	<0.0001	<0.0001	

a, b, c Means in a row with different superscripts differ significantly ($p < 0.05$). A, B Means in a column with different superscripts differ significantly ($p < 0.05$).

Table 6 shows significant differences between the three types of environmental enrichment over the course of all four weeks, with the A-Reuter having the lowest number and the Plateau having the highest. However, there were no significant differences within the individual enrichment elements A-Reuter and the Plateau over the course of the four weeks. Regarding the Hybrid, there were significant differences between weeks one and two compared with weeks three and four where the number of birds was significantly lower.

As Table 7 indicates, slight differences were apparent when considering the number of birds per square metre on the different types of environmental enrichment.

Table 7. Average number of birds per square meter on the different types of environmental enrichment over the course of three trial rounds ± standard deviation in the trial groups (TG) at the time of taking photographs.

	Week 1	Week 2	Week 3	Week 4	*p*-Value
"A-Reuter"	0.10 ^{a} ± 0.07	0.18 ^{a} ± 0.17	0.13 ^{a} ± 0.07	0.21 ^{a} ± 0.07	0.2885
"Plateau"	18.68 ^{b} ± 3.06	18.28 ^{c} ± 2.43	18.90 ^{c} ± 1.45	19.01 ^{c} ± 2.25	0.9518
"Hybrid"	16.24 ^{bB} ± 3.27	15.84 ^{bB} ± 1.92	13.54 ^{bA} ± 1.06	12.69 ^{bA} ± 1.42	0.0002
p-Value	<0.0001	<0.0001	<0.0001	<0.0001	

a, b, c Means in a row with different superscripts differ significantly ($p < 0.05$). A, B Means in a column with different superscripts differ significantly ($p < 0.05$).

Table 7 shows no significant differences between the Plateau and the Hybrid for week one. In weeks two to four, the same significant differences between all types of environmental enrichment are seen as in Table 5.

3.2.2. Kilogramme per Square Metre

In Table 8, the respective kg per area for each type of enrichment are displayed.

Table 8. Average mass in kg per square meter of each environmental enrichment ± standard deviation in the trial group.

	Week 1	Week 2	Week 3	Week 4	*p*-Value
"A-Reuter"	0.02 ^{aA} ± 0.01	0.10 ^{aA} ± 0.09	0.14 ^{aB} ± 0.08	0.35 ^{aC} ± 0.12	<0.0001
"Plateau"	3.70 ^{cA} ± 0.62	9.77 ^{cB} ± 1.26	19.76 ^{cC} ± 1.51	31.93 ^{cD} ± 3.74	<0.0001
"Hybrid"	3.09 ^{bA} ± 0.62	8.45 ^{bB} ± 1.04	14.29 ^{bC} ± 1.12	21.36 ^{bD} ± 2.40	<0.0001
p-Value	<0.0001	<0.0001	<0.0001	<0.0001	

a, b, c Means in a row with different superscripts differ significantly ($p < 0.05$). A, B, C, D Means in a column with different superscripts differ significantly ($p < 0.05$).

As shown in Table 8, significant differences between the Plateau and the Hybrid were apparent over the weeks, with the Plateau having the highest values overall. The A-Reuter had significantly lower values compared with the Hybrid over the course of all weeks.

Table 9 indicates the differences between the displayed values in Table 8 and the average kg/m^2 in the trial group.

Table 9. Difference in mass per kg on each type of enrichment to the average kg per square metre of the barn ± standard deviation of the trial group (TG).

	Week 1	Week 2	Week 3	Week 4	*p*-Value
"A-Reuter"	−3.25 ^{aD} ± 0.02	−8.87 ^{aC} ± 0.06	−17.59 ^{aB} ± 0.08	−27.88 ^{aA} ± 0.12	<0.0001
"Plateau"	0.45 ^{c} ± 0.62	0.79 ^{c} ± 1.26	2.03 ^{c} ± 1.51	3.70 ^{c} ± 3.74	0.0637
"Hybrid"	−0.16 ^{bC} ±0.62	−0.53 ^{bC} ± 1.04	−3.44 ^{bB} ± 1.11	−6.87 ^{bA} ± 2.39	<0.0001
p-Value	<0.0001	<0.0001	<0.0001	<0.0001	

a, b, c Means in a row with different superscripts differ significantly ($p < 0.05$). A, B, C, D Means in a column with different superscripts differ significantly ($p < 0.05$).

As shown in Table 9, only the mass per square metre for the Plateau was higher than the average over the course of all four weeks. The Plateau was also significantly higher than the Hybrid in all week. The values for A-Reuter were significantly the lowest.

3.3. Free Space

Table 10 shows the weekly average of free space in the barn for nine fattening rounds.

Table 10. Average value of free space ± standard deviation for each week over the course of nine trial rounds.

	Week 1	Week 2	Week 3	Week 4	Week 5
Free space	81.84 ± 5.53	74.56 ± 3.72	62.70 ± 4.37	56.91 ± 4.62	52.38 ± 7.61

As seen in Table 10, the average free space decreased continuously from week one to week five.

Table 11 compares the free space in different zones of the barn over the course of five weeks. For each zone, the weekly average values during the trial with and without enrichment are displayed.

Table 11. Average values of free space ± standard deviation in the different zones of the trial group in the trial rounds with environmental enrichment and without environmental enrichment over the course of five weeks.

		Week 1	Week 2	Week 3	Week 4	Week 5
Zone 1	enriched	79.48 ± 5.51	74.91 ± 2.63	62.63 ± 4.25	58.06 ± 6.44	52.70 ± 9.33
	non-enriched	82.81 ± 5.51	77.95 ± 5.89	65.04 ± 2.72	60.65 ± 1.65	59.20 ± 2.84
Zone 2	enriched	79.71 ± 5.69	69.48 ^{a} ± 3.25	55.74 ^{a} ± 5.05	51.51 ^{a} ± 6.63	45.00 ± 9.14
	non-enriched	83.13 ± 8.59	77.42 ^{b} ± 5.95	65.25 ^{b} ± 5.05	57.69 ^{b} ± 4.99	57.64 ± 5.25

Table 11. *Cont.*

		Week 1	Week 2	Week 3	Week 4	Week 5
Zone 3	enriched	81.82 ± 5.94	73.60 ± 3.50	61.58 ± 4.52	55.33 ± 5.72	46.80 ± 8.42
	non-enriched	80.81 ± 7.02	75.33 ± 3.72	62.56 ± 2.81	52.70 ± 2.18	55.05 ± 9.71
Zone 4	enriched	80.16 ± 5.72	72.67 [a] ± 3.62	59.91 [a] ± 6.15	54.69 ± 6.27	48.32 ± 11.43
	non-enriched	82.90 ± 7.58	80.00 [b] ± 5.52	73.46 [b] ± 4.61	58.15 ± 4.54	56.77 ± 9.83
Zone 5	enriched	81.80 ± 5.08	75.12 ± 3.18	63.41 ± 4.46	57.82 ± 4.98	51.59 ± 7.42
	non-enriched	83.83 ± 6.03	77.83 ± 2.87	67.50 ± 1.80	58.65 ± 1.60	59.23 ± 6.31

a, b Means in column in one zone with different superscripts differ significantly ($p < 0.05$).

As Table 11 shows, there were significant differences in Zone 2 and Zone 4 between the enriched and non-enriched trial rounds. The non-enriched trial rounds showed significantly higher values of free space compared to the enriched trial rounds.

4. Discussion

4.1. Influence of the Design and Material on the Usage of the Environmental Enrichment Elements

The design and material of the environmental enrichment elements might have influenced the usage of the different types of them. Lower usage might have been caused by the fact that the industrially manufactured perches were not perfectly fitted for the birds. The diameter of the perches were too large and the small birds were not able to grip the perches optimally with their feet (In our study the diameter was 1.90 cm. Only later, at higher age the birds were able to jump and hold on the perches). Therefore, we found the highest frequency of use with 2.17 as an average in week four.

It is also possible that the birds were not used to the perches in young age and did not explore them sufficiently. Also the size of the perches could have resulted in uncomfortable seating positions for the birds, which makes it less attractive for them to sit there. This contrasts with findings of Bailie and O'Connell who used similar perches in previous studies [34].

Another reason for the little use of the perches could be the height above the floor. If the broilers can only reach the perches with difficulty or have to make a great effort to do so, then the incentive of perching might not have been sufficiently strong. Norring et al. observed that broilers mostly used the lowest available perches only which they could reach easily [35]. This could also explain the lowest value with 1.00 in week one when the birds are at their smallest and therefore have the most difficulties in reaching the perches.

Furthermore, the material used for the "A-Reuter" should also be scrutinised. Metal is easy to clean and disinfect, but it is much harder and probably more slippery as well as uncomfortable than natural materials such as wood. Hongchao et al. observed a higher use of wooden perches compared to synthetic materials in their study [36].

4.2. Usage of the Different Environmental Enrichment Elements

All of the three tested types of environmental enrichment elements were used by birds although the frequency and intensity of usage differed among the different types. The least used type was the "A-Reuter" perch in our trials. It was used significantly less by birds than the other types as described in Table 6 (a maximum value of 2.17 compared to 49.00 and 68.67 for "Hybrid" and "Plateau", respectively). These results align with previous studies showing a general low use of perches by broilers [37–39].

The same applies to the use of the combinated element, the "Hybrid", which were used significantly less compared to the platforms ("Plateau") (highest values 49.00 compared to 68.67 for the "Plateau"). This difference in the use of perches compared to platforms agrees with Kaukonnen et al. [27].

In animals per square metre, these figures were ahead of the "A-Reuter" (16.24 vs. 0.21), but far behind the "Plateau" with a value of 19.01. Compared to the perches of the "A-Reuter", the material could have been advantageous, as the perches were made of plastic. This material is softer than metal and thus more comfortable for the animals' feet. The texture of the perch could also be advantageous. The provided version was not completely round but only rounded on the upper side, which can contribute to a better grip on the perch.

The "Plateau" was used the most of all environmental enrichments in our study, with the average number of birds per square meter ranging between 18.28 and 19.01. There were no differences in the later weeks compared to the earlier weeks, although the animals in the later weeks were clearly larger and heavier. Table 7 shows that the highest value with an average of 19.01 birds per square metre on an environmental enrichment element was even found in week four.

The same development can be seen with kg per square metre where the "Plateau" showed significantly higher values in all four weeks than the other elements (highest value of 31.93 compared to 0.35 for the "A-Reuter" and 21.36 for the "Hybrid". Also, in comparison to the overall average in the whole barn, only the "Plateau" was above average, with up to 3.7 kg more per square metre in week four. These results are aligned with those of Malchow et al. who also observed a higher use of elevated structures the higher the age of the birds [37].

In order to gain insight into how the elements were used by the birds, a total capacity was calculated for each type of environmental enrichment (Appendix A). To calculate this capacity, values of 22 cm per bird for perches [38] and 303.3 cm^2 per bird for plain spaces [39] based on the available data from scientific literature were used.

The utilisation in per cent for the A-Reuter was the lowest of all types of enrichment (1.71%) followed by the Hybrid (19.36%). The highest values were seen for the Plateau with more than half of the theoretically available space covered by bird (57.80%).

4.3. Evaluation of Free Space

The free space was compared between enriched and non-enriched trial rounds, and there were significant differences between those (see Table 10). However, the differences were only apparent for weeks two and three in Zone 2 and Zone 4, as those were the zones with the enrichment elements. These results indicate that an enriched area in the barn can be more attractive to birds. Zone 2 with 69.48 and 55.74% of free space and Zone 4 with 72.67 and 59.91% of free space showed the lowest numbers for weeks three and four in trial rounds with enrichment elements. These results are aligned with those of Ventura et al., who also observed higher numbers of birds in areas with the provision of enrichment elements [26]. In non-enriched trial rounds, the values regarding the free space for these zones were as high or even higher than in the rest of the barn which describes lower numbers of birds when environmental enrichment was absent. This could be related to the fact that broilers are eager to climb elevated structures when these are available [26].

These effects disappeared in weeks four and five, which could also be related to the growth of the broilers, which, in the later stages of fattening does not allow them to choose the space as readily as in earlier weeks.

4.4. Influence of Environmental Enrichment on Growth Performance

The provision of environmental enrichment in this trial did not show negative influence on body weight gain or growth performance, although recent studies have shown otherwise [40,41]. Significantly higher values regarding the body weight for birds housed without enrichment was described by de Jong et al. [40], while Nazareno et al. recently recorded increased body weights with the provision of those [41]. This could be related to the easier accessibility of the platforms used by de Jong et al., which were equipped with ramps. This might have increased the frequency of use of that environmental enrichment and therefore resulted in higher body weights for the birds housed without enrichment. In this trial, the results do not align with either of the findings described above. The results of this trial regarding the growth performance align with those of Jacob et al., who also described no influence of environmental enrichment regarding this factor [42]. The comparison of the FCR also showed no significant differences. This is in accordance with findings of de Jong et al. who did not find a difference in FCR between enriched and non-enriched groups in their trials [40].

5. Conclusions

In conclusion, this study shows a significantly higher use of elevated platforms compared with perches for broilers. The provision of these environmental enrichment elements displayed no negative influences on growth performance and also had neither positive nor negative influences on the FPD scores in our trial. There were signs that enriched areas were more attractive to the birds than non-enriched ones. Further research regarding the type, design and construction of environmental enrichment elements for broilers should be carried in larger production units.

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Appendix A

In order to be able to describe the actual utilisation of the individual elevated seating possibilities as environmental enrichment in a somewhat more striking way, the maximum capacity of each variant was first calculated on the basis of defined standard values from the scientific literature, where Brandes et al. described the space requirement on a perch for broilers at d 28 with 22 cm [38] and Spindler et al., described the floor space requirement for a broiler at d 28 with 303.3 cm^2 [39] Afterwards, the value for the actual utilization was calculated by dividing the average number of birds at d28 by the total capacity.

Table A1. Calculation of the utilisation rate for the environmental enrichment elements with values for space requirements resulting from the scientific work of Brandes et al. [38], and Spindler et al. [39].

Variant of Enrichment	A-Reuter	Plateau	Hybrid
Space requirement	22 cm/Bird	303.3 cm^2/Bird	303.3 cm^2/Bird
Total space available	28 m/element	3.6 m^2/element	6 m^2/element
Total capacity for birds	127.27	118.81	198.02
average number of birds at d28	2.17	68.67	38.33
Utilisation (in %)	1.71	57.80	19.36

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