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EFFECTS OF DIFFERENT TYPES OF ENVIRONMENTAL ENRICHMENT ON BEHAVIOUR, PERFORMANCE, WELFARE, CARCASS CHARACTERISTICS AND LIPID PROFILE OF BROILER CHICKENS

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ORIGINAL ARTICLE

Effects of Different Types of Environmental Enrichment on Behavior, Performance, Welfare, Carcass Characteristics, and Lipid Profile of Broiler Chickens

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Abstract

OBJECTIVES: This study aimed to examine how different environmental enrichment items affect broiler behavior, performance, welfare parameters, and blood profiles.
MATERIALS AND METHODS: A total of 200 1-day-old Cobb 500 broiler chicks were used in a 35-day trial. Of these chicks, 200 Cobb 500 broiler chicks were allocated into control and three treatment groups of 25 birds each in two replicates. The environmental enrichment items were straw bales in treatment A, elevated platforms (5 cm wooden platform) in treatment B, and increased distance between the feeder and the drinker by 3.5 m in treatment C. Behavioral patterns of broiler chickens were monitored for 4 consecutive weeks. Food intake and mortality were recorded daily and body weight was recorded weekly. The gait score was assessed on days 32, 33, and 34, while footpad dermatitis, hock burns, and blood biochemistry were assessed on day 35.
RESULTS: Broiler chickens reared under different environmental enrichment regimens appeared more active and exhibited maintenance behaviors (preening, wing flapping, and floor pecking) more frequently than the nonenriched control birds. No enrichment effect was observed for productive performance traits. Regarding welfare traits and blood profiles, there was an overall tendency toward a lower gait score and lower levels of total cholesterol, low-density lipoprotein, and non-high-density lipoprotein in birds that experienced different enrichment tools.
CONCLUSION: The addition of environmental enrichment tools (straw bales, elevated platforms, and increased distance between resources) appeared to motivate the birds for physical activities and to improve health and walking ability, without negatively influencing growth performance parameters.

Keywords: Behavior, Blood profile, Elevated platforms, Enrichment, Straw bales

1. Introduction

The provision of environmental enrichment provides a complexity that enables animals to make choices that enhance their quality of life. Enriched environments can hasten animal welfare, boost feelings of pleasure, interest, and comfort, and provide a sense of control by providing animals with opportunities to engage in rewarding behaviors such as food searching (foraging), exploration, and social interactions [1].

In addition, environmental enrichment can potentially improve animals' cognitive development, stimulate positive emotional states [2], and give them the capacity to employ resources and adapt to changes [3]. These benefits are particularly relevant for modern commercial poultry housing systems.

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In contrast to jungle fowls, modern broiler chickens spend 60−80% of their day sitting and sleeping [4]. Along with rapid growth rates and high body weights, a high level of inactivity is regarded as a major risk to broiler health [5]. An increased incidence of contact dermatitis is positively associated with prolonged contact with litter because of inactivity [6].

Environmental enrichment has been practiced in recent years to improve the living environments of animals and birds in captivity. Five types of enrichment regimens have been increasingly used to enrich the environment of animals under the care of humans. The first practice is the social enrichment of the environment by housing animals together with conspecifics in groups. The second practice is the physical enrichment of the environment by increasing the complexity or adding physical structures and additional accessories to the environment. The third practice is the nutritional enrichment of the environment by scattering food items in the substrate or bedding so that the animals spend time searching for it. The fourth practice is the psychological enrichment of the environment by increasing the possibilities for animals to control their environment, and the fifth practice is the sensory enrichment of the environment by providing aids that can reduce the reactivity of animals to sudden background noises, such as playing radios softly during the day [7].

One approach found to be successful with regard to increasing activity is to force broilers to travel longer distances to attain vitally important resources such as feed and water. This can be achieved by increasing the distance between the feed and water [8], allocating barriers in the environment [9], or by scatter feeding, in contrast to trough feeding [10].

Another approach to increasing the activity levels of broilers is to provide environmental enrichment that stimulates active behaviors, such as locomotion, dustbathing, and foraging. These can be point-source elements, such as straw bales, highly valued feed items (e.g. mealworms, insects, roughage), and different dustbathing substrates. Some studies have explored single types of point-source enrichment [8], whereas others have investigated the effects of combining a range of enriching elements [11,12].

Exploratory behaviors have been demonstrated to increase by providing straw bales as an environmental enrichment item; at the beginning, birds used it as a protected resting area, which can reduce the stress of animals that feel threatened during preening and resting behaviors [13]; then, the bird uses it as an exploration area, thereby increasing the occurrence of exploratory behavior represented by pecking at straw bales [14].

Furthermore, using platforms as enrichment resources has been reported to increase the physical challenge to birds [15] and to provide them with an elevated place where they can rest and perform the basic natural behavior of surveillance against predators. It has been revealed that the use of platforms facelifted a variety of behaviors that may enhance birds' coordination and musculoskeletal strength, such as jumping off the platforms and walking up and down [16]. Extending the distance between feeding and drinking areas has also been shown to increase physical activity and improve the ability of fast-growing broiler chickens to walk [15,16].

Fearfulness, panting, spatial distribution, dust-bathing, scratching, pecking, and cannibalism have been used as indicators of animal welfare because these behaviors can reflect the emotional status of avians [17]. Improving poultry production could be achieved by decreasing harmful behaviors, such as fearful behaviors or feather pecking, stimulating normal behavior, or doing both. Productivity has been reported to be negatively related to underlying fearfulness. Fearful birds generally show poorer growth and food conversion efficiency, lower reproductive performance, increased incidence of eggshell abnormalities, compromised hatchability, and reduced product quality [18,19].

The current study was therefore designed to assess the effectiveness of using different environmental enrichment resources such as straw bales, elevated platforms, and extended distances between feeders and drinkers on broiler behavior, performance, blood profile, and welfare of broiler chickens.

2. Materials and methods

2.1. Birds and husbandry

The present study was conducted at a commercial broiler farm located in El-Dakahlia Governorate, Egypt. A total of 200 newly hatched and unsexed Cobb 500 broiler chicks were used in this study. They were obtained from a commercial hatchery and randomly allocated into four experimental pens with a 3 m^2 floor space with a stocking density of nine birds/m^2. Each treatment group was represented by two replicates (25 birds per replicate group and 50 birds per treatment group). Chicks were vaccinated for infectious bronchitis, Newcastle disease, and Marek's disease at the hatchery.

The study was conducted during summer (August 2021), and a 4-cm high wood shaving litter material was provided as bedding on the pen floor. At chick placement, the average air humidity was 61.8% and the ambient temperature was maintained at 34 °C and was gradually reduced to 20 °C from day 28 of age and for the rest of the study. The air was pulled into the house by two small fans located on either side of each house and was exhausted by eight large fans located on the long-axis end of the house. The chicks were fed a commercial broiler starter (21.7% CP and 3.060 kcal of ME per kg) from 1 to 14 day, a grower diet (19.7% CP and 3.163 kcal of ME per kg) from 15 to 28 days, and a finisher diet (17.6% CP and 3.212 kcal of ME per kg) from 29 to 35 days. Nutrients and energy concentrations of diets met or exceeded the NRC minimum nutrient recommendations [20].

2.2. Experimental design

The study consisted of a control and three treatment groups of 50 birds each. All treatment groups included different types of environmental enrichment. Treatment A consisted of a pecking substrate in the form of three straw bales of 43 × 40 × 70 cm (height × width × length) that were evenly distributed on the floor of the pen. These bales were designed to boost the pecking and locomotor activity of the birds in the pen. In treatment B, rectangular perforated plastic slats (5.4 m × 0.6 m) were placed 5 cm above the bedding and were provided as elevated platforms. In treatment C, the distance between feed troughs and the drinkers increased to 3.5 m contrasted to a distance of 1.5 m in the remaining control and treatment groups.

2.3. Behavioral observations

Fifteen individual birds were randomly chosen per pen and marked using wing tags, and their behaviors were observed. The behavior of birds in each of the four groups was recorded in real time using an instantaneous sampling method with 30-s intervals between consecutive groups. Each sample interval was prompted by an audio cue through headphones, and the behavior was recorded on a check sheet. Recordings were taken for 4 days each week between weeks 2 and 5 of the rearing cycle. All behavioral observations were taken for 1 h during four distinct periods of the day: 9:00, 12:00, 16:00, and 19:00 h. Each observation session therefore yielded 30 scans per group per day (observation week). This meant a total of 120 scans per group over the entire experimental period (4 observation weeks).

The observer walked slowly to the pen, waited 1 min to allow birds to habituate for his presence, and then counted the number of broilers performing each of the following behaviors (sleeping and lying down as inactive behaviors; standing, walking, and jumping as locomotor behaviors; eating and drinking as intake maintenance behaviors; preening, dustbathing, and wing flapping as nonintake maintenance or comfort behaviors; and nonaggressive feather pecking and floor pecking as exploratory behaviors) [21] (Table 1).

2.4. Productive performance

The body weights of the chicks were measured on arrival and afterward. These were measured individually every week. Data on feed consumption were recorded daily from the second to fifth week of the rearing cycle on a pen basis. Feed consumption (g) was calculated as the difference between the weight of the food offered in the morning and the weight of the remaining food the following morning. Feed conversion per pen was estimated by dividing the amount of feed consumed (g) during the week by weight gain (g) during the same week.

Table 1. Ethogram of behavioral elements recorded.

Behavior	Definition
Lying down	The bird lies with the head resting on the ground or erected. The eyes may be open or closed
Sleeping	The bird's neck is fully recumbent, and its eyes are fully closed
Standing	The bird is motionless with no activity and its abdomen is not in contact with the ground
Walking	The bird is moving forward at a steady walking pace
Jumping/flying	The flapping of the wings forces the bird to be lifted from the ground
Eating	The bird's head is above the feeding trough or pecking at the feed within the feeder
Drinking	The bird's beak is in contact with water in or above the drinker
Preening	The bird uses its beak to arrange or trim feathers
Dustbathing	The bird is bathing in the litter with the use of its head, neck, legs, and wings
Wing flapping	The bird extends both wings out from the body simultaneously and flapping wings
Feather pecking	The bird is pecking the feathers of another bird
Floor pecking/scratching	The bird pecks the litter in search of food or scratches the litter with its feet in a backward movement

Chicks were monitored regularly, and any incidence of mortality was recorded per pen daily.

2.5. Blood sampling and analysis

One blood sample (6 ml per bird) was taken by wing venipuncture of five birds with equal body weights from each treatment group on the 35th day of the study. Each of the 20 collected blood samples was divided into two portions in two different vacutainer tubes, and the first portion was drawn into vacutainer tubes containing anticoagulant dipotassium ethylenediaminetetraacetic acid (K2EDTA) for whole blood collection for complete blood count and hematological parameters. Hematological parameters included red blood cell count that was measured according to the method of Natt and Herrick [22]. Hemoglobin concentration (Hb) was measured according to the method described by Benjamin [23]. Packed cell volume was measured according to the protocol described by Stoskopf *et al*. [24]. Hematocrit value, mean corpuscular volume, mean corpuscular hemoglobin, mean corpuscular hemoglobin concentration, and red blood cell distribution width were also assessed.

The second portion of the blood sample was collected into tubes without anticoagulant and centrifuged for 6 min at 3000 rpm speed. The serum was then separated and preserved at -20 °C and then sent to the laboratory for total cholesterol, triglycerides, low-density lipoprotein (LDL), high-density lipoprotein (HDL), and non-high-density lipoprotein (non-HDL) lipid profile analyses. Serum concentrations of total cholesterol, triglyceride, LDL, and HDL were analyzed using an enzymatic colorimetric method [25] with commercial kits (Spinreact Co., Girona, Spain) according to the manufacturer's instructions using a spectrophotometer (Milton Roy, Spectronic 1201, Houston, TX, USA).

2.6. Organ weight and carcass characteristics

Twenty broilers (five birds from each treatment group) were sampled randomly for carcass evaluation on the 35th day of the study. They were fasted for 12 h, individually weighed, killed by decapitation, and feathers were mechanically removed following a hot water scald. The heart, liver, pancreas, lungs, gizzard, and proventriculus were excised and weighed. The relative weights of these organs were calculated by dividing the organ weight by the preslaughter live body weight and by the dressed carcass body weight (with visceral weight, after the birds were scalded and feathers were removed) multiplied by 100.

2.7. Welfare indicators

2.7.1. Gait score

Data were collected during the last 3 days before slaughtering, where the mean age at scoring was ~33 days. Ten random birds in each treatment group were observed while moving from one part of the room toward other parts without a walking stimulus. The scoring of individual broilers took between 5 s and 2 min, and birds that did not walk away within ~2 min were encouraged to walk by a person walking slowly behind them. Birds were assessed for lameness using the six-point gait scoring system [26]. Birds with normal walking ability were scored 0, birds with slight defects that were difficult to define were scored 1, birds with defined defects that did not hinder their movement were scored 2, birds with obvious gait abnormalities that affected their ability to move were scored 3, birds with severe gait defects were scored 4, and birds with complete lameness were scored 5.

2.7.2. Footpad dermatitis

All flocks were kept on fresh bedding material. The litter quality was maintained by adjusting the temperature and ventilation. Footpad dermatitis was evaluated in five random birds from each treatment group. The footpads of the right and left feet were examined, and scoring was performed at slaughter by visual inspection and palpation [27]. Feet with no lesions were scored 0; feet with small lesions (lesions on <25% of footpads) were scored 1; those with moderate lesions on one or both feet (lesions on >25% but <50% of footpads) were scored 2; and score 3 was assigned to birds with extensive lesions on one or both feet (lesions on >50% of footpads).

2.7.3. Hock burns

The scoring of the hock lesions comprised a four-point scale system. Hocks with no lesions were assigned a score of 0, those displaying minor discoloration or small lesions were scored 1 and 2 when there were moderate lesions on one or both hocks, and those with extensive lesions and severe scabbing were scored 3 [27].

2.8. Statistical analysis

Upon confirming the normality of the data distribution using the Shapiro−Wilk test, statistical analyses were performed using SPSS, software version 23.0 (IBM SPSS Statistics for Windows, Version 23.0.; IBM Corp., Armonk, New York, USA). The effect of the treatment on behavior was analyzed using a generalized linear mixed model. One-way analysis of variance was used to investigate the effects of treatment on productive performance traits, relative organ weight, gait score, footpad dermatitis, hock burns, and blood profile. Data are reported as mean ± SEM, and Duncan's multiple range test was used as a post-hoc test to determine the nature of the interactive significant effect between treatment groups. Differences were considered statistically significant at P value less than or equal to 0.05.

3. Results

3.1. Effect of environmental enrichment on behavior expression of broiler chicken

Environmental enrichment had a significant effect on the percentage of birds standing, lying down, walking, jumping, preening, wing flapping, and floor pecking. Birds that had experienced environmental enrichment were more active throughout the rearing period. A higher percentage of birds stood in treatment A (straw bales), treatment B (5 cm elevated platforms), and treatment C (3.5 m between feed and water) compared with the control ($P < 0.01$, 0.05, 0.01, respectively) (Fig. 1). The highest number of birds walking was reported in birds reared in treatment C compared with the control and other environmentally enriched groups ($P < 0.001$). Birds provided with straw bales walked more than those in the control group ($P < 0.01$) (Fig. 2). Meanwhile, broilers provided with 5-cm elevated platforms performed more jumping than those in the control group, treatment A, and treatment C ($P < 0.001$) (Fig. 3). However, the lack of environmental enrichment in the control group increased inactivity and lying down of broilers compared with those that experienced environmental enrichment in treatments A, B, and C ($P < 0.001$) (Fig. 4). Maintenance behavior was more pronounced in birds provided with straw bales, elevated platforms, and increased distance between resources as environmental enrichment tools. Birds in the control group showed the lowest percentages of preening and wing flapping compared with those in treatments A, B, and C (preening, $P < 0.01$, 0.05, 0.001, respectively) (Fig. 5) (wing flapping, $P < 0.05$) (Fig. 6). It is important to note that differences between birds that experienced the various environmental regimens provided in the study in terms of comfort behavior (preening and wing flapping) were not significant. In addition, broilers who had access to straw bales in treatment A showed more ground-directed exploratory behavior, including floor pecking, than those in the control group and treatments B and C ($P < 0.001$) (Fig. 7).

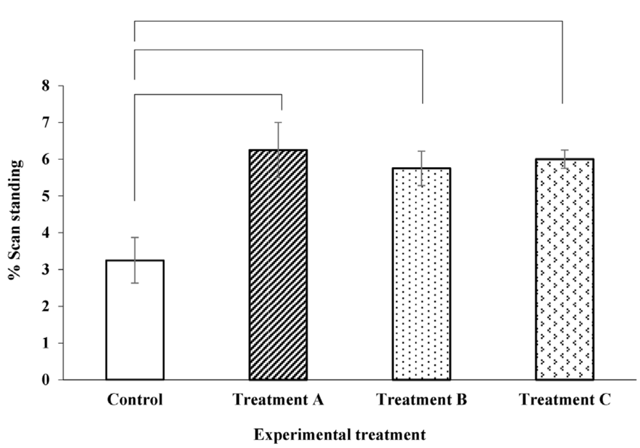

*Fig. 1. Mean ± SE average % scan standing by broiler chickens in different treatment groups. *P value less than 0.05, **P value less than 0.01.*

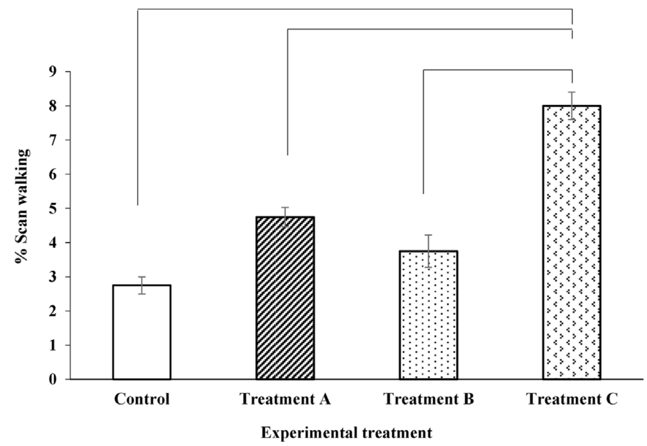

*Fig. 2. Mean ± SE average % scan walking by broiler chickens in different treatment groups. ***P value less than 0.001.*

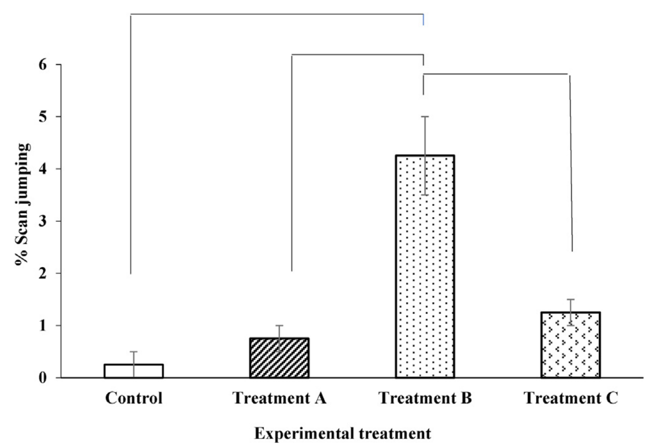

*Fig. 3. Mean ± SE average % scan jumping by broiler chickens in different treatment groups. ***P value less than 0.001.*

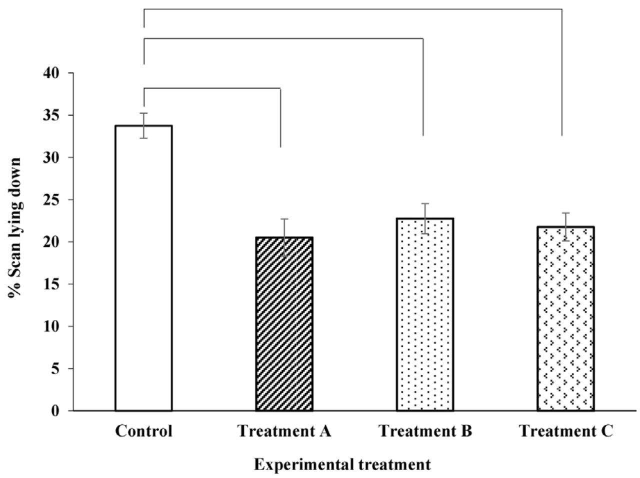

*Fig. 4. Mean ± SE average % scan lying down by broiler chickens in different treatment groups. ***P value less than 0.001.*

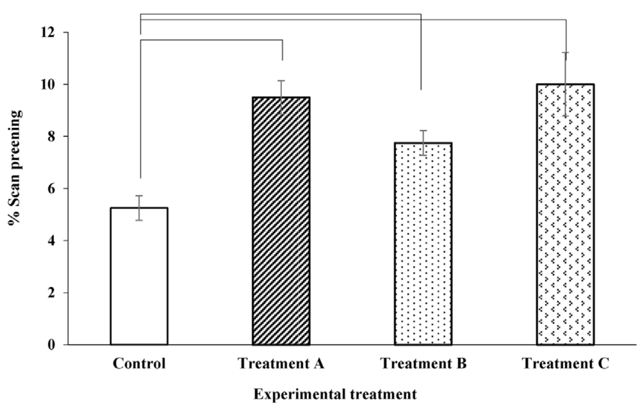

*Fig. 5. Mean ± SE average % scan preening by broiler chickens in different treatment groups. *P value less than 0.05, **P value less than 0.01, ***P value less than 0.001.*

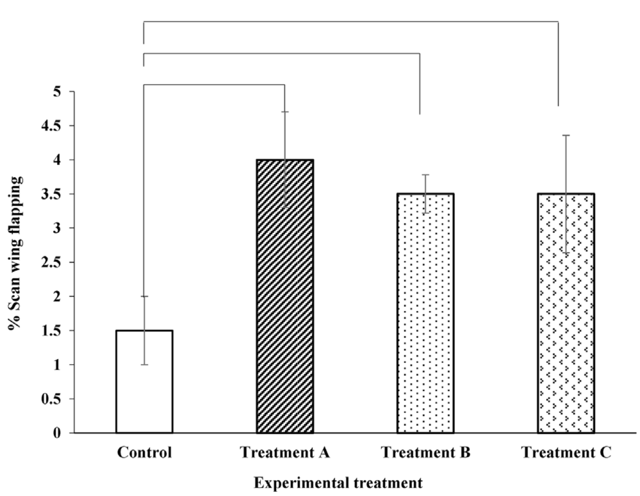

*Fig. 6. Mean ± SE average % scan wing flapping by broiler chickens in different treatment groups. *P value less than 0.05.*

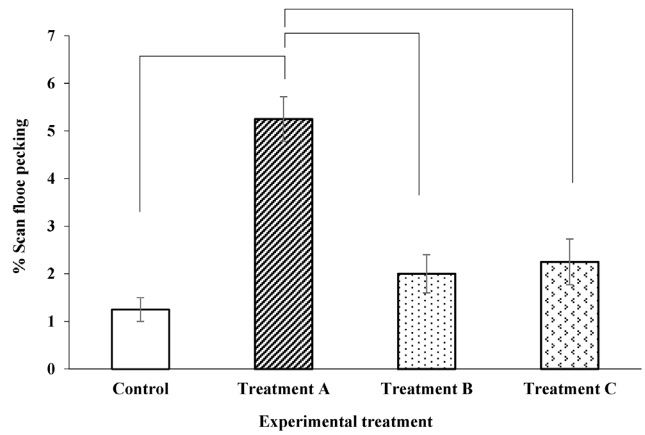

*Fig. 7. Mean ± SE average % scan floor pecking by broiler chickens in different treatment groups. ***P value less than 0.001.*

3.2. Effect of environmental enrichment on productive performance traits of broiler chicken

Body weight did not differ ($P > 0.05$) between the control and treatment groups at 7, 21, and 35 days of age. However, on day 14, broilers reared with 3-cm elevated platforms were heavier than those provided with increased distances between feed and water ($P < 0.05$). At 28 days of age, broilers with platforms for environmental enrichment in treatment B had heavier weights than those with straw bales in treatment A ($P < 0.01$). There was no significant difference in daily average feed consumption throughout the rearing period between any of the enrichment and control groups. Similarly, experimental treatment did not affect body weight gain at weeks 3 and 4. However, in week 5, broilers in the control group and treatment B showed higher body weight gain than those in treatment C ($P < 0.01$) (Table 2).

3.3. Effect of environmental enrichment on blood biochemistry of broiler chicken

The blood biochemistry of 35-day-old broiler chicks is presented in Table 3. The use of various environmental enrichment regimes did not affect the values of hemoglobin, red blood cell count, hematocrit, mean corpuscular volume, mean corpuscular hemoglobin, mean corpuscular hemoglobin concentration, triglycerides, HDL, and very LDL in broiler chickens under different treatments. However, the highest total cholesterol, LDL, and non-HDL values were reported in birds in the control group compared with those in treatments A, B, and C ($P < 0.001$, 0.05, 0.05, respectively).

Table 2. Productive performance traits of broilers in different experimental groups (mean ± SEM).

Body weight	Control	Treatment A	Treatment B	Treatment C
Week 1	191.50 ± 3.57	188 ± 7.18	193.50 ± 3.16	190 ± 3.49
Week 2	470.00 ± 10.95^{ab}	481.50 ± 10.91^{ab}	489.50 ± 12.16^{a}	452.00 ± 11.33^{b}
Week 3	891.50 ± 13.08	863.00 ± 12.54	912.00 ± 12.97	890.00 ± 13.05
Week 4	1737.00 ± 43.48^{ab}	1694.00 ± 29.89^{b}	1792.00 ± 28.23^{a}	1752.00 ± 30.03^{ab}
Final	2150.00 ± 66.24	2055.00 ± 57.93	2215.00 ± 62.63	2090.00 ± 55.59
Food intake				
Week 2	375.90 ± 10.80	365.25 ± 14.05	375.17 ± 14.07	372.10 ± 12.23
Week 3	671.05 ± 5.69	668.90 ± 9.60	632.00 ± 10.10	657.48 ± 9.89
Week 4	989.12 ± 39.12	1000.05 ± 28.45	951.85 ± 39.35	980.34 ± 17.18
Week 5	1205.20 ± 4.90	1177.20 ± 3.70	1136.35 ± 34.05	1172.91 ± 15.48
Body weight gain				
Week 2−3	421.14 ± 21.00	381.45 ± 19.00	422.50 ± 11.25	438.80 ± 15.48
Week 3−4	845.50 ± 38.50	831.75 ± 26.87	880.23 ± 35.42	862.50 ± 19.00
Week 4−5	413.40 ± 15.00^{a}	361.52 ± 27.35^{ab}	423.00 ± 12.03^{a}	338.03 ± 21.43^{b}

Means within the same row having different superscripts are significantly different at *P* value less than or equal to 0.05.

Table 3. Blood biochemistry profile of broilers in different experimental groups (mean ± SEM).

	Control	Treatment A	Treatment B	Treatment C
Hemoglobin	9.60 ± 0.96	9.86 ± 1.79	10.46 ± 42	11.16 ± 0.32
Red blood cell count	2.10 ± 0.23	1.72 ± 0.14	1.76 ± 0.14	2.03 ± 0.26
HCT	31.66 ± 3.17	32.33 ± 6.35	34.33 ± 1.33	36.66 ± 0.88
MCV	154.00 ± 22.12	196.33 ± 46.62	201.66 ± 23.46	174.33 ± 6.11
MCH	46.33 ± 6.69	59.33 ± 14.11	61.00 ± 7.09	53.66 ± 0.66
MCHC	31.46 ± 0.31	30.43 ± 0.37	30.43 ± 0.13	30.70 ± 0.25
Total cholesterol	217.33 ± 8.24^{a}	141.33 ± 7.31^{b}	185.00 ± 2.08^{b}	161.33 ± 2.96^{b}
Triglycerides	49.33 ± 5.04	76.00 ± 25.23	63.00 ± 9.01	86.33 ± 28.48
HDL	62.66 ± 17.16	45.66 ± 2.96	65.66 ± 12.41	37.66 ± 7.17
LDL	137.00 ± 0.57^{a}	85.33 ± 5.36^{b}	106.33 ± 11.83^{b}	104.66 ± 10.65^{b}
VLDL	17.00 ± 5.53	16.00 ± 1.04	12.50 ± 1.75	15.00 ± 5.03
Non-HDL	154.66 ± 5.66^{a}	95.66 ± 6.17^{b}	119.33 ± 13.61^{b}	120.33 ± 11.60^{b}

HCT, hematocrit; HDL, high-density lipoprotein; LDL, low-density lipoprotein; MCH, mean corpuscular hemoglobin; MCHC, mean corpuscular hemoglobin concentration; MCV, mean corpuscular volume; VLDL, very low-density lipoprotein.
Means within the same row having different superscripts are significantly different at *P* value less than or equal to 0.05.

3.4. Effect of environmental enrichment on relative organ weight of broiler chicken

The relative organ weights of broiler chickens reared under different environmental enrichment conditions are presented in Table 4. No significant differences ($P > 0.05$) in the relative weights of the gizzard, proventriculus, heart, pancreas, and liver were found among birds in the different treatment groups.

3.5. Effect of environmental enrichment on welfare traits of broiler chicken

The welfare traits of commercial broilers differed under the different environmental enrichment protocols. There was an overall tendency toward a lower gait score (i.e. reduced lameness) in the enriched groups (A, B, and C) than in the non-enriched group ($P < 0.05$). Nevertheless, experimental treatments did not affect the prevalence of footpad dermatitis and hock burns ($P > 0.05$) (Table 5).

4. Discussion

The present study aimed to encourage the physical activity of broiler chickens and increase the number of birds moving and exploring by adopting three different environmental enrichment tools (straw bales, elevated platforms, and increased distance between resources) and evaluating their

Table 4. Relative organ weight of broilers in different experimental groups (mean ± SEM).

	Control	Treatment A	Treatment B	Treatment C
Gizzard relative weight (%)	1.78 ± 0.07	1.67 ± 0.04	1.79 ± 0.07	1.70 ± 0.09
Proventriculus relative weight (%)	0.52 ± 0.08	0.55 ± 0.06	0.61 ± 0.06	0.56 ± 0.10
Heart relative weight (%)	0.47 ± 0.11	0.41 ± 0.08	0.55 ± 0.10	0.50 ± 0.13
Pancreas relative weight (%)	0.83 ± 0.12	0.84 ± 0.01	0.89 ± 0.11	0.89 ± 0.13
Liver relative weight (%)	2.48 ± 0.10	2.50 ± 0.18	2.46 ± 0.06	2.65 ± 0.19

Table 5. Gait score, footpad dermatitis, and hock burns of broilers in different experimental groups (mean ± SEM).

	Control	Treatment A	Treatment B	Treatment C
Gait score (GS)	2.00 ± 1.00[a]	0.33 ± 0.33[b]	0.67 ± 0.33[b]	0.33 ± 0.33[b]
Footpad dermatitis	0.67 ± 0.33	0.00 ± 0.00	0.33 ± 0.33	0.00 ± 0.00
Hock burns	0.67 ± 0.33	0.33 ± 0.33	0.33 ± 0.33	0.33 ± 0.33

Means within the same row having different superscripts are significantly different at *P* value less than or equal to 0.05.

effects on behavior, performance, leg health, blood biochemistry, and carcass traits.

Broiler chickens that used different environmental enrichment tools were more active throughout the rearing cycle. They exhibited higher levels of movement and exploration and were less inactive than those in the nonenriched control group. These results support those of Kells *et al*. [28], who found increased levels of standing and locomotion and decreased levels of sitting and resting when birds were provided with a pecking substrate as straw bales. In contrast, Bailie and O'Connell [29] found no effect of straw bales on the general level of activity or on the time spent standing and moving. The conflicting results of these studies could be explained by the discrepancy in the number and density of straw bales used.

In this study, broiler chickens were more motivated to walk when the distance between the feeder and the drinker increased by 3.5 m. Hence, increasing the distance between resources could be considered a promising practical strategy to encourage birds to move and to increase locomotion, and to improve leg health. Similar to previous research, increased activity was observed when the distance between the feed and water was extended, especially in the first 2 weeks of age. This early increase in activity has been shown to positively affect the leg health of broilers, as demonstrated by an increased walking ability, longer latency to lie, a tendency of improved bone-breaking strength, and reduced twisting and bending of leg bones [8,30]. However, Bach *et al*. [31] found no increase in locomotive behavior when the distance between resources was increased, which was attributed to the presence of a large barren area in the pen without any protective cover, leading to broilers increasing their tendency to stay near feeding troughs and water nipples instead of being homogeneously distributed in the pen.

The fact that applying elevated platforms in the current study increased the urge to move and increased the number of birds engaged in jumping behavior indicates that they were highly motivated to use elevated structures and that the use of platforms of a low height (5 cm) did not constitute a physical challenge for birds to use them. This may be of particular importance for broiler chickens that are heavy and bred for muscle size, which makes it challenging for them to reach perches of a higher height [32]. Previous studies have suggested that perching behavior, including perching on platforms, could encourage a wide variety of locomotor activities, which might be beneficial for welfare [29,30]. Elevated platforms can stimulate large behavioral repertoires such as jumping, grasping with edges, and flying attempts. However, only jumping was observed in this study. Broiler chickens exhibited preferences toward elevated platforms over perches, probably due to the physical challenges involved in perching [32]. Rearing broilers with elevated platforms from an early age has been correlated with improved leg health [15].

Interestingly, broiler chickens under different environmental enrichments exhibited maintenance behaviors (preening and wing flapping) and exploratory behaviors (floor pecking), particularly in treatment A more frequently than in the control group, which implies that a more stimulating environment promoted the bird's motivation to self-maintain and explore. Moreover, the addition of elevated platforms in treatment B offered a variety of active behaviors that were occasionally accompanied by vigorous wing flapping, which may explain the finding of higher levels of wing flapping in this treatment. The most likely explanation for these behavioral expressions in birds reared in environmentally enriched groups was that when broiler chicks were supplied with different enrichment tools from early life, they started to explore these structural and visual materials, due to being born nidifugous with a well-developed brain [33].

These enrichments not only stimulate physical activities but also produce excitement in birds, and hence, they express maintenance behaviors more frequently [34]. This is consistent with the findings of other studies that found that the addition of metal perches, wood shaving, and chains as environmental enrichment tools motivates physical activity and stimulates explorative behaviors in broiler chickens [34]. Indeed, comfort behaviors were more frequently performed on the platforms compared with the other types of enrichment (straw bales, decreased stoking density) in a study by Bach *et al*.

[31], supporting the correlation between perching and performance of comfort behaviors and proving that platforms may represent an alternative, elevated structure that provides easy access at all ages [35,36].

It has been shown that providing enrichment tools such as bales of lucerne hay, peat, and elevated platforms promotes the activity of commercial broiler chickens during the rearing cycle and boosts specific locomotory, exploratory, and comfort behaviors [37]. Pecking behavior was also well-motivated in birds reared with straw bales as pecking substrates. This finding indicates that the need for pecking is not satisfied by feeding alone.

The results of the present study suggest that environmental enrichment did not affect the growth performance of broiler chickens at 35 days of age. This implies that the presence of environmental enrichment in treatments A, B, and C, and the assumed higher energy consumption, which is expected to result from the increased physical activity stimulated by the enriched environment, had no negative impact on the body weight of broiler chickens at slaughter age. Similarly, in previous studies [31,38], feed intake, feed conversion ratio, and final body weight were not negatively affected when the distance between resources was extended. It is possible that the duration of feeding and drinking bouts was not affected, and the increased activity did not influence energy expenditure to the extent that it had a negative effect on the productive performance of broiler chickens [38]. These results also corroborated the findings of Bizeray *et al*. [30] and Nazareno *et al*. [39], who stated that the application of environmental enrichment did not reduce production but improved bird welfare. In contrast, other studies have shown that an increase in the physical activity of birds had a negative impact on body weight development [40].

Broilers with access to straw bales, elevated platforms, and increased distance between resources in treatments A, B, and C had better gait scores than those in the control group, with no enrichment. Broilers are particularly vulnerable to skeletal disorders that impede mobility, as they can spend up to 76−86% of their time budget lying down by slaughter age [4]. In turn, this inactivity may lead to worsening skeletal health and additional disorders, such as contact dermatitis [6]. These leg disorders are painful, and birds with gait scores greater than 2 are considered to have poor welfare [41]. When broilers are motivated to exercise at a young age, they show a drastic reduction in leg disorders due to slaughter age. This finding further supports the connection between inactivity and poor leg health [6,42]. The findings of previous trials also showed that increasing the environmental complexity of broilers by providing straw bales, barriers, perches, and elevated platforms boosts activity [9,28]. In a recent study by Mocz *et al*. [12], a decrease in walking ability was evident when stocking density was increased. However, this negative effect of increased stocking density was only found in groups of broilers without access to enrichment. However, no effect of environmental enrichment with straw bales and elevated platforms on walking ability has been reported in previous studies [13,29].

Nevertheless, there was a tendency toward low scores of footpad dermatitis and hock burns in birds in the control and enriched groups, despite the difference in activity levels in these groups. These low scores may reflect good litter conditions in the different treatment groups. Previously, it was hypothesized that rearing broilers with perches and platforms enable them to rest without direct contact with litter, which could reduce the risk of footpad dermatitis and hock burns [12]. However, our results contradict these assumptions, as the hock burn and footpad dermatitis scores were very low in the present study, which may indicate that the conditions in the experimental groups were not challenging enough to show the effects of enrichment.

Birds reared in the environmentally enriched groups showed the lowest values of total cholesterol, LDL, and non-HDL compared with those in the control group. It is possible that birds reared in the enriched groups had less fear; hence, the birds were healthier and had normal blood profiles. The findings of the present study are supported by other studies that found that the addition of perches and hay bales as environmental enrichment decreased stress levels in commercial broiler chickens [43]. In addition, studies in humans have found that regular physical activity has a positive effect on cholesterol metabolism [44]. In agreement with the results of our study, Özbey and Esen [45] reported a significant reduction in the serum total cholesterol concentration of rock partridges kept on the ground compared with that in cages. A positive correlation has been found between reduced physical activity and fat deposition in children [46] and reduced fat mass in rats [47].

5. Conclusion

In conclusion, activity was mainly increased when birds received different enrichment tools, whereas the performance of specific active behaviors varied between treatments. Thus, the present study illustrated that various types of environmental manipulation of existing resources have different effects on the activity and behavior of broiler chickens. Broilers interacted more frequently with jumping platforms, whereas floor pecking was performed more frequently on straw bales than on any of the other types of enrichment investigated. The provision of an extended distance between resources increases the walking tendency. Furthermore, we found that the provision of enrichment from an early age offered more opportunities for birds to move, self-maintain, explore, and express their natural behavior, which in turn improves health, well-being, and leg condition without having deleterious effects on growth performance or welfare parameters. However, it should be considered that the adoption of environmental enrichment has cost implications and may put additional time demands on stockmen.

Further studies are needed to investigate the effects of enrichment regimens implemented in this study on other measures of welfare in broiler chickens, such as physiological (e.g. plasma levels of corticosterone), psychological (e.g. tonic immobility test), pathological (histopathology of internal organs, particularly thymus and spleen), and immunological measures (e.g. total level of immunoglobulins in the blood or other body fluids, and the rate of proliferation response of T-lymphocytes to stimulation with mitogens). Moreover, the low power of the study should also be acknowledged and may require testing these enrichment regimens on a larger scale. Therefore, despite the small sample size of the study, significant effects of reatments reported in the current study were large.

Declarations

Research Ethics Committee permission

The study protocol was approved by the Research Ethics Committee of the Faculty of Veterinary Medicine, Mansoura University, Egypt (VM.MS.23.02.43).

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Data availability statement

The authors confirm that the data supporting the findings of this study is available within the article.

Authors' contribution

Rana A. Elsayed designed the study protocol and supervised data collection procedures, Asmaa S. Mohammed analyzed the data and shared in the experimental protocol, and Usama A. Abou-Ismail, Mohammed M. Fouda, Ragab A. Darwish, and Ahmed F. Abou-Elnaga shared in writing the manuscript. All authors finalized the experimental design, revised the manuscript, and contributed to, edited, and approved the final manuscript as submitted.

Conflicts of interest

There are no conflicts of interest.

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