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Effects of Housing Systems on Behaviour, Performance and Welfare of Fast-growing Broilers

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ABSTRACT: This experiment aimed to evaluate the effects of different housing systems on behavioral activities, welfare and meat quality of fast-growing broilers. Two hundred broilers were allocated into two housing systems: indoor housing vs indoor with outdoor access. Their general behavior (feeding, drinking, fighting, standing, lying, walking, investigating, dust-bathing and preening) was observed, and tonic immobility, fluctuating asymmetry of legs and wings were measured, and meat quality was analyzed. The results showed that the indoor-housed broilers with outdoor access had significant higher standing, walking, investigating, dust-bathing and preening than those indoor only. However, farming system was not found to significantly affect their feeding, drinking and fighting activities ($p>0.05$). The value of FA of tibia length of the broilers with outdoor access was significantly lower than that of the indoor-housed birds (1.57±1.30 vs 2.76±1.40, $p<0.05$), while no difference was found for the value of FA in tibia diameter and wing length ($p>0.05$). TI of the broilers with outdoor access was 165.5 that was significantly higher than that (147.2) of the indoor birds ($p<0.05$). However, death rate in the outdoor run groups was significantly higher than that of the indoor ones (2.0±0.81 vs 4.0±0.82, $p<0.05$). Meat quality was not affected by the two farming systems. It can be concluded that the results of this study may suggest that the indoor housing with outdoor access provides enriched environment for broilers and facilitates the expression of natural behaviors of the broilers but resulted in poorer performance and higher death rate. (**Key Words:** Broiler, Housing System, Welfare, Behavior, Meat Quality)

INTRODUCTION

Birds under free-range or organic systems have access to an outside area where an enriched environment can promote their foraging, feed selection, and activity and theoretically the welfare of the birds can be improved (Ponte et al., 2008). Such systems coupled with high standards of animal welfare can provide special poultry products related to a greater quality and security of meat which are the increasing preference of consumers in Europe and the United States (Fanatico et al., 2006). Environmental enrichment can foster and encourage natural behaviors (Duncan, 1987; Newberry, 1995; Stricklin, 1995) and create a greater number of behavioral opportunities (Newberry, 1995; 1999; Newberry and Estevez, 1997; Mellen and MacPhee, 2001). The benefits of enrichment to chickens are numerous and include encouraging a more-even distribution of animals (Cornetto and Estevez, 2001), reducing disturbances and aggression (Cornetto et al., 2002b), and reducing fear responses and stress (Jones, 1982; Nicol, 1992; Reed et al., 1993; Grigor et al., 1995; Bizeray et al., 2002). In chicken, laying hens in a free range system may show beneficial behavioral elements which are not possible in the poultry house (Zelnter and Maurer, 2009). Therefore, access to free range can improve welfare and allow birds to show complete sunbathing behaviour in direct sunlight while it is not shown in artificial light. Ruis et al. (2004) concluded that an outdoor run potentially also improves welfare of broilers. They found that natural light as such does not guarantee a better welfare, but that it is likely that the quality and intensity of lighting is of importance. Thus it appears that the access to a free range area is very important for poultry. However, it is also reported that the birds in outdoor systems are exposed to several factors including infectious and parasitic diseases, social interactions, and adverse climatic conditions (in outdoor systems) that may increase both stress and fear reactions and reduce welfare

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(Campo et al., 2008). In China the most commercial broilers are kept in conventional rearing systems although there are a few hens and slow-growing broilers raised in free-range systems, and nearly no fast-growing broilers are found in free range systems. The study was carried out in Northeast of China to evaluate the effects of indoor-housing system with outdoor access on behaviour, performance and welfare of fast-growing broilers, and to explore the possible practice of such a system in that region.

METHODS AND MATERIALS

Experimental design and animal management

The experiment was carried out in the Experimental Farm of Northeast Agricultural University, Harbin (China) from August to October 2010. A flock of 1-d AA commercial broiler chicks were raised up to 21 days of age in a fostering room and the experiment started at their 22 days of age. Room temperature was kept at 33°C for the first three days and then was reduced by 2 to 3°C each week. Artificial ventilation inside the room was allowed to maintain relative humanity about 60 to 70%. Lighting was 24 h for the first week after hatching and reduced to 20L/4D until 21 d. On d 22 two hundred of healthy females selected from the flock with average body weight (BW) of 673.6±20.1 g were transferred to a testing house, and randomly allocated into two treatments: indoor housing and indoor with outdoor access treatments (100 birds per treatment). There were two sections in the house where one of which possessed free access to outdoors. Inside the house a 5 cm depth of a mixture of wood shaving and chopped dry grass were provided as bedding materials (litter). The outdoor condition was soil of which 30 to 40% area was covered by natural vegetation. In each treatment there were 4 groups (replicates) each of which contained 25 birds/group. The indoor conditions remained similar for both treatments over the experimental period and stocking density was set for 10 birds/m^2 for the indoor pen due to the limitation of the room structure. The groups with outdoor run were provided with a 40 m^2 outdoor run area with a sunshade net that covered 25% of the area for sheltering. Natural ventilation was adopted and artificial lighting allowed 20 h of lighting per day. The outdoor ambient temperature for day and night ranged from 25 to 29°C during the experimental period and relative humanity was ranged 50 to 72%. The birds with outdoor access were released at 08:00 h and housed at 18:00 h and during the day time they were free to go in or out of the house. Feeders and water drinkers were placed in both pens and running areas, so that all birds had free access for feed and water. The chicks were fed a starter diet (CP: 21.0% and ME: 3,200 kcal/kg) from 0 d to 21st day of age and then switched to a finisher (CP: 19% and ME: 3,150 kcal/kg) up to 49th d. Feed consumption and BW were measured weekly and their feed conversion efficiency was determined. Death of birds was checked every day and balanced for feed conversion.

Behavioral observation

Twelve wide angle video cameras (FS-EH303, Shenzhen Feihongxin Technology Company, Shenzhen, China) were located over 8 pens and 4 outdoor run areas for monitoring bird activities. Ten birds from each pen (group) as focal animals were marked on neck and back with 5 colors of waterproofed, non-toxic dyes (black, red, blue, yellow and pink). Focal Animal Sampling was adopted during behavioral sampling. The observations were conducted on d 40 and d 42 and their behavioral activities were recorded. During each observation day recording started at 08:00 am for 150 min and at 14:00 pm again. Each focal animal was sampled every 5 min and then 30 samples were collected from each individual over each observation. Behavioral categories were divided into state behaviors (lying, standing, walking and investigating) and event behaviors (feeding, drinking, fighting, preening, feather pecking and dust-bathing). The definitions of the behaviours were given in Table 1. The state behavioral parameters were sampled every 5 min on each focal animal with scan sampling over 150 min period and represented as percentage of total occurrences. The event behavioral parameters were recorded with continuous sampling over 150 min (from each focal animal) and represented as frequency of occurrences.

Tonic immobility duration and fluctuating asymmetry determination

Five birds from each pen (replicate) were randomly selected on d 47. They were brought into a separate room and the induction of tonic immobility (TI) was conducted as the procedure described by Jones and Faure (1981). If a bird righted itself in less than 10 s, then it was considered as the failure of inducing TI and the bird would be induced again. If three inductions failed, the bird was scored 0 s. If the bird did not show a righting response over a10-min test period, a maximum score of 600 s was given (Campo et al., 2008). On d 49 another 5 birds from each pen were selected and slaughtered. The measurements of the length and diameter of tibia, and the length of wing were conducted, and FA of tibia and wing were determined following the method given by Palmer and Strobeck (1992).

Meat quality determination

At 49 d, all remaining birds were weighted after 12 h fasting and slaughtered and the eviscerated carcass weight

Table 1. Behavioural categories and the definitions

Behavioral categories	Definitions
State behaviors	
Standing	Standing without any other activity
Walking	Locomotion with a normal speed or with quick steps
Lying	Broilers' abdomen contacts with the floor or both legs are twisted under the body.
Investigating	Broiler is pecking at the floor or at other parts of the pen (but not at the food) or it is standing/moving with its head in a lower position than the rump.
Event behaviors	
Drinking	Broiler directs its beak to nipple drinker and raises its head when getting water.
Feeding	Broiler directs its beak to feed trough and carries out pecking or eating, once or repeatedly
Fighting	Frontal displays with raised hackles towards another bird, head pecking, jumping or kicking at another bird attacking the other birds in an aggressive manner.
Feather pecking	Broilers' beak pecking at the feathers of other individuals.
Preening	Broiler directs its beak to its own plumage of several body parts (thorax, abdomen, shoulder, interior and exterior wings, rumps, back, and cloaca) and carries on pecking, nibbling, combing or rotating movements, once or repeatedly.
Dust bathing	Bathing the dust with the use of wings, head, neck and legs performing vertical wing-shaking.

was measured. Abdominal fat was taken off from the eviscerated carcass and calculated as a percentage of the eviscerated carcass weight. Muscle samples were collected from the left side of the pectoralis major muscle for meat quality analysis. Crude fat was extracted from the left fillet sample after water loss measurement and expressed as a percentage of an initial muscle weight. pH_1 value was determined with a portable pH meter (pH 3110, Shanghai Muchen Electronic Technical Co., Ltd) calibrated at pH 4.0 and pH 7.0 on 5 g of meat samples taken from the left fillets 45 min postmortem. Meanwhile another 5 g of the samples were wrapped with plastic bags and cooled at 4°C for 24 h and measured for pH_2 value. Shear force test was conducted by vertically shearing cube samples of 1 cm×1 cm×1 cm taken from the left fillets with a Warner-Braztler shear force method. Before shear force measurement the fresh samples were kept in plastic bags and cooled at 4°C for 24 h and then cooked at 80°C for 45 min until the internal temperature cooled to room temperature. Drip loss was determined by a filter paper pressing method described by Wang et al. (2009). Raw fillet samples were suspended on hooks and the initial weights were measured after keeping at 4°C for 24 h. Then the meat samples were placed on filter papers and reweighed after pressing. Drip loss was expressed as a percentage of the initial weight of the original sample. Cooking loss followed the measuring method described by Allen et al. (1998). The fillets were placed on aluminum trays, cooked for 20 min at 95°C, allowed to cool for 30 min, and reweighed to calculate cooking loss.

Gait score test

One day before the end of the experiment, 10 birds from each treatment were taken and put into an adjacent room for a gait score test (Kestin, et al., 1992). The scoring system in this study was defined as Score 0 (normal): walks at least ten steps with ease and is well balanced; Score 1: Slight defect in the gait; Score 2: obvious defect-limping, unsteady; Score 3: only walk with difficulty when driven or strongly motivated; Score 4: incapable of walking. A score of 4 was not recorded as these birds would have been culled prior to the GS test.

Statistics

One-way ANOVA repeated measurement design was used to analyze the effect of the treatment and the observing periods within a day in behavioral activities. No interaction of the treatment and observing days was found in behavioral activities, therefore behavioral data for each individual over two days was pooled. Arcsin transformation was conducted for all behavioral data before analysis. Logarithmic transformation was conducted for TI data before analysis due to abnormal distribution. All results were presented as mean±SD and $p<0.05$ was considered as significant.

RESULTS

Effects on behaviour of fast-growing broilers

The results in Table 2 show that the broilers with an outdoor run had significantly higher preening, dust-bathing, and lower feather pecking, and engaged more in standing, walking and investigating but less lying than the indoor birds ($p<0.05$). However, no difference was found in feeding, drinking, and fighting between the two systems ($p>0.05$). Over the observational periods the birds housed indoors did not show a significant difference between the

Table 2. Effect of rearing system on behavioral activities[1, 2, 3]

Rearing system	Event behaviours					
	Drinking	Feeding	Fighting	Feather pecking	Preening	Dust-bathing
Indoor (n = 40)	3.86±0.95	12.65±1.23	0.13±0.05	2.42^a±0.98	3.75^a±1.03	0.56^a±0.04
Outdoor run (n = 40)	3.45±0.74	10.78±1.45	0.16±0.04	2.21^b±0.74	6.52^b±0.85	2.69^b±0.63
	p = 0.015	p = 0.021	p = 0.071	p = 0.032	p = 0.021	p = 0.012

Rearing system	State behaviours			
	Standing	Lying	Walking	Investigating
Indoor (n = 40)	12.24^a ±1.45	79.16^a±2.97	4.14^a ±1.13	4.46^a ±1.22
Outdoor run (n = 40)	16.16^b±1.76	70.68^b±2.67	6.42^b±1.21	6.74^b±1.25
	p = 0.024	p = 0.033	p = 0.022	p = 0.014

a,b Different superscript indicates significant difference at p<0.05. [1] n = 4 replicates with 25 birds per replicate in each treatments.
[2] Mean represented as frequency of occurrences. [3] Mean represented as percentage.

morning and afternoon sections in lying, standing, walking and investigating activities, but within the treatment with outdoor run lying activity of the birds in the afternoon was found to be higher than that in the morning (60.58% vs 80.81%, p<0.05); higher morning preening and standing was also found (p<0.05).

Effects on performance of the broilers

The results (Table 3) show that although weekly feed intake was not found to be significantly different between the two systems (638.19 g±10.43 for indoor only birds vs 645.89 g±11.76 for the outdoor run birds, p>0.05) but that a significantly higher finishing BW and lower feed growth ratio was found for indoor only birds compared with the outdoor run ones (p<0.05). Abdominal fat content was higher for the indoor only birds than the outdoors (2.21% ±0.77 vs 1.61%±0.55, p<0.05). However, mortality rate in the outdoor run groups was significantly higher than that of the indoor ones (2.0±0.81 vs 4.0±0.82, p<0.05).

Effects on meat quality

The results of effects of rearing system on meat quality are given in Table 4. No difference was found in pH_1, pH_2, drip loss, cooking loss and crude fat between the two systems but the only significant difference was found for shear force that was higher for the outdoor run birds the indoor birds (2.39±0.15 vs 1.66±0.16, p<0.05).

Effects on welfare conditions of the broilers

FA of the tibia of the outdoor-run birds was found significantly higher (p<0.05) than the indoor birds (Table 5). However, FA of tibia diameter and wing length did not show significant difference between the two systems (p>0.05). Also the tonic immobility duration for the outdoor-run birds was longer than that of the indoor (p<0.05). The results in Table 6 show that there was no significant difference found for gait score between the two systems (p>0.05), but the number of the birds with high gait scores was found to be higher for the indoor groups than the outdoor run groups.

DISCUSSION

Impact on behavioral activities

Environmental enrichment has been reported to increase the birds' behavioral repertoire, to reduce underlying

Table 3. Effect of rearing system on the performance of broiler

Rearing system	Mortality rate (%)	BW (g)	Weekly feed intake (g)	F:G[1]	Abdominal fat (%)
Indoor (n = 100)	2.0^a±0.81	2,250^a±112.3	638.19±10.43	1.62^a±0.01	2.21^a±0.77
Outdoor run (n = 100)	4.0^b±0.82	1,998^b±101.4	645.89±11.76	1.97^b±0.11	1.61^b±0.55
	p = 0.031	p = 0.025	p = 0.023	p = 0.034	p = 0.024

a,b Different superscript indicates significant difference at p<0.05. [1] Value represented as ratio.

Table 4. Effect of rearing system on meat quality

Rearing system	pH_1	pH_2	Crude fat (%)	Drip loss (%)	Cooking loss (%)	Shear force (kg)
Indoor (n = 40)	6.96±0.38	6.46±0.19	0.87±0.27	1.79±0.82	36.75±7.31	1.66^a±0.16
Outdoor run (n = 40)	6. 63±0.43	6.43±0.17	2.23±0.17	2.23±0.17	6.59±1.88	2.39^b±0.15
	p = 0.102	p = 0.123	p = 0.097	p = 0.088	p = 0.076	p = 0.036

pH_1 = Muscle pH value in broiler slaughtered 45 min. pH_2 = Muscle pH value after broiler slaughtered 24 h.
a,b Different superscript indicates significant difference at p<0.05.

Table 5. Effects of rearing system on FA and TI duration in broilers

Rearing system	FA of tibia	FA of tibia diameter	FA of wing length	TI duration
Indoor (n = 40)	1.57[a] ±1.30	2.78±2.14	6.22±1.06	147.2[a]±51.67
Outdoor run (n = 40)	2.76[b] ±1.40	2.51±1.70	6.59±1.88	165.5[b]±46.38
	p = 0.012	p = 0.061	p = 0.058	p = 0.028

[a,b] Different superscript indicates significant difference at p<0.05.

Table 6. Effects of rearing system on Gait Score (GS)

Rearing system	GS = 0	GS = 1	GS = 2	GS = 3	FCS
Indoor (n = 40)	62.5±2.54	15.2±0.45	8.1[a]±0.60	12.4[a]±1.54	71.45±5.11
Outdoor run (n = 40)	71.0±3.03	16.4±0.77	10.7[b]±0.57	5. 2[b]±0.52	69.75±2.44
	p = 0.064	p = 0.084	p = 0.042	p = 0.031	p = 0.072

[a,b] Different superscript indicates significant difference at p<0.05.

fearfulness, to lessen feather pecking, to decrease the incidence of trauma and injury, and to improve overall health and productivity of flocks (Jones, 2002; Leone and Estěvez, 2008). Campo et al. (2008) also reported that under alternative outdoor or indoor housing systems resembling more natural conditions where chickens were provided with a richer environment they performed greater behavioral repertoire than those in cages. The results of our study supported the above reports where more natural behaviors such as preening, dust-bathing, walking and investigating were found for the broilers with outdoor access than the indoor birds. Grass, insects, soil and other surroundings may attract a bird to explore its environment so higher activities for the birds with outdoor access than indoor birds are plausible. Kells et al. (2001) reported that even provision of bales attracted birds to perch on and cluster around them and were more active than birds in an un-enriched house. Not just broilers or laying hens, growing pigs in enriched environment also perform more locomotory behaviour than those in a barren environment (Beatie et al., 1995). In this study the birds having less feather pecking in the enriched environment also indicated that birds had more opportunities to react to natural stimuli instead of partners. Similar results can be seen elsewhere (Jones, 2002). Thus, the more activities and natural behavioral expression shown by the birds with outdoor access in this study may indicate an enhanced welfare.

Impact on performance

Animals having more activities would exhaust more energy and consume more feed. The results of the experiment indicated that the more active birds with the outdoor run system ate slightly more feed, but had significant lower weekly gain, feed conversion and abdominal fat content compared to the indoor housed birds. It can be argued that although the higher activities were found for the birds with outdoor excess in this study, the level of energy expenditure spent by the birds may not have reached the point at which the birds had to eat more to compensate for the extra energy consumption. Hot ambient temperature during the experiment may have been another factor suppressing the birds' appetite. The latter may be more likely to be the attributor to feed intake. However, higher activities resulted in lower feed conversion efficiency and lower abdominal fat content for the outdoor access birds in this study. The relative high death rate for the outdoor groups may indicate that risk of diseases were more likely to be the main reason. It has reported that in free range system broilers or hens are facing increased risk from helminth infection (Permin et al., 1999) and Salmonella (Hoop and Albecker Rippinger, 1997).

Impact on meat quality

For slow-growing broilers, Fanatico et al. (2005) and Wang et al. (2009) found that a free range system or indoor system with outdoor access did not affect nutrient composition (pectoralis dry matter, fat, protein, water, and ash). Our study supported their finding that protein, drip loss and fat were not affected by the two systems. However, the results of that shear force increased 28.9% for the outdoor run birds compared with the indoor birds agreed with that reported by Wang et al. (2009). This may indicate that more activities could result in relative strong muscle fibers that affect meat tenderness. Fanatico et al. (2005) also reported that the meat tenderness of fast growing broilers may be affected by farming system, and age may also be another factor determining meat tenderness (Fletcher, 2002).

Impact on welfare conditions

The results showed that FA of tibia length of the outdoor run birds was significantly higher than that of the indoor birds but FA of tibia diameter and wing length was not significantly different between the rearing systems. This may indicate that FA is not a suitable indicator for determining the welfare state of fast-growing broilers due to the fast growth of the broilers selected for heavy BW and high feed efficiency may mask adverse environmental effects during the developmental processes (Van Poucke et al., 2010).

The duration of TI is often used to indicate the fearfulness of hens (Hensen et al., 1993; Campo et al., 2008) or broilers (Sanatro et al., 2001) under various housing conditions. Several studies reported that increased environmental complexity may decrease fearfulness of broilers (Hughes and Black, 1974; Jones and Waddington, 1992). However, our study showed that the birds with outdoor run showed a significant longer duration of IT than the indoor birds, which contradicted the above findings. Although environmental complexity can help reduce fearfulness of birds (Jones, 2002), Zeltner and Maurer (2009) argued that when birds encounter a non roofed run area they feel unsafe so that only small proportion of the flock is outside at the same time. We would like to argue that although the access to a run area can enrich birds' behavioral repertoire, it can also increase the opportunity for them to encounter unpleasant environmental stimuli such as road traffic or predatory birds over flying. These stimuli may increase the alertness of the birds and when they are caught they will show a greater degree of alertness than those without the outdoor experience. Thus, a high IT value for them may be explained in this study.

CONCLUSION

Our study suggests that provision of an outdoor run for fast-growing broilers could facilitate birds to express a more natural behaviour and thereby improve their welfare state; however, this would be at a cost of reduced performance and meat tenderness and increased death rate.

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