Poultry rearing on perforated plastic floors and the effect on air quality, growth performance, and carcass injuries—Experiment 1: Thermal Comfort

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ABSTRACT The present study investigated the use of perforated plastic floors in the rearing of male and female poultry under thermal comfort conditions. The study was conducted in 2 climate chambers, in one was conventional poultry litter (wood shavings) and in the other was a perforated plastic floor. The experimental design was a completely randomized design with the factors wood shavings and plastic floor. In each chamber, the animals were divided into 16 experimental pens (8 with males and 8 with females) with a density of 12 birds/m^2. The poultry rearing effect was evaluated in terms of air quality (% concentration of ammonia [NH_3] and carbon dioxide [CO_2]); broiler performance, e.g., weight gain (kg), feed intake (kg), feed conversion, carcass yield and parts (%), meat production (kg/m^2), and viability (% of live birds at d 42); scores of hygiene and mobility; and injuries in the chest, hocks, and footpads. Treatments affected air quality, with higher concentrations of NH_3 on d 42 (25 ppm vs. 2 ppm) and CO_2 (1,400 ppm vs. 1,000 ppm) for wood shavings than for perforated plastic floor, respectively. Males showed a better performance (weight gain, feed intake and feed conversion) than females on d 42 in both floor types (wood shavings and plastic floor). Males reared on wood shavings showed a higher meet production (35.992 kg/m^2) than females (32.257 kg/m^2). On the plastic floor, males showed a better viability (100%) than females (94.05%), as well better meet production for males (38.55 kg·m^{-2}) than females (31.64 kg/m^2). There was no incidence of breast lesions in any of the studied systems. The birds reared on the plastic floor had better hygiene scores and lower hock injury rates than birds reared in the wood shavings chambers. The results of the present study show that the use of perforated plastic floors in chicken farming is an efficient method, which promotes a better-quality environment, superior production rates, and reduced incidence of injuries.

Key words: Plastic floor for broiler, Ammonia concentration, Carcass injury, Poultry litter, Animal Welfare

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INTRODUCTION

According to the United Nations (2013), the world population is expected to exceed 9.6 billion by 2050, implying that the production of food is a growing concern. With this in mind, poultry meat is highly valued because it is an animal protein of high quality, can be produced in a short period at relatively low cost, and can meet the demand of the population. In 2015, Brazil was the second highest world producer of poultry meat, with a production of 13.15 million tons (ABPA, 2016). However, further research and the establishment of technologies that allow production in higher quantities without harm to animal welfare and that generate less waste are necessary.

Annually, approximately 7.8 million tons of poultry litter is produced in Brazil (Benites et al., 2010). The main materials used as poultry litter are wood shavings, rice husks, and peanut shells (Miles et al., 2011). Owing to the high cost and the difficulty in finding poultry litter material, producers reuse the same material for several cycles of breeding in an attempt to reduce production costs (Lopes et al., 2013). However, according to Medeiros et al. (2008), this reuse of poultry litter over a number of breeding cycles increases the potential of the undesirable effects of ammonia ($\mathbf{NH_3}$) accumulation occurring. Exposure to high concentrations of NH_3 causes a decrease in poultry performance (Miles et al., 2004), affects the immune system (Wei et al., 2015), and increases susceptibility to disease (Beker et al., 2004). This exposure can also affect the health of workers who are in daily contact with this gas (Rylander and Carvalheiro, 2006).

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Inadequate management practices that impoverish poultry litter quality may produce severe impacts on animal welfare, lower hygiene, and increased carcass injury incidence, thus causing considerable losses in production (de Jong et al., 2014). One possible solution might be to use a perforated plastic floor, similar to those used for rearing pigs, where the poultry residues would be constantly removed from inside the installation, avoiding decomposition and consequently the production of NH_3. The acquisition cost of poultry litter material would also be reduced, as would the overall creation of waste. The use of plastic floors is already a reality in some branches of poultry production, such as the breeding of laying hens (Heerkens et al.,2015) and duck breeding (Karcher et al., 2013; Rice et al., 2014; Fraley et al., 2013; Xie et al., 2014). However, until now, few studies have been found in the literature reporting the effects of using plastic floors in the production of broilers (Li et al., 2016).

The objective of this study was to evaluate the use of perforated plastic floors as a replacement for poultry litter (wood shavings) for broilers reared under a thermal comfort environment.

MATERIALS AND METHODS

Facilities, Poultry and Management

The present study was conducted at São Paulo State University (UNESP) Jaboticabal, Brazil, using broiler chickens, male and female from the commercial line, Cobb500®, aging from 1 to 42 d (Globo aves, Itirapina, São Paulo, Brazil). The birds were distributed in 2 climate chambers, one with wood shavings as litter material and the other with a perforated plastic floor (Big Dutchman, Araraquara, São Paulo, Brazil).

The birds were raised in thermal comfort, following the recommendations for this particular line described in the Cobb Breeder Management Guide (Cobb, 2008). The broilers were fed a nutritionally balanced diet from 1 to 21 d of age (initial phase) and from 22 to 42 d of age (growing phase) formulated following the nutritional requirements established for broilers under tropical conditions by Rostagno et al. (2011) (Table 1). Throughout the experimental period, the birds received water and feed ad libitum. The chicks were vaccinated against Marek's disease, avian pox, infectious bursal disease, and Newcastle disease, according to the Cobb(®) vaccination program.

Design and Experimental Treatments

A total of 384 broilers were distributed in a completely randomized design in 2 climate chambers, one with a perforated plastic floor and the other with wood shavings. In each chamber, the animals were divided into 16 boxes (8 with males and 8 with females) with dimensions of 0.9 × 1.2 m each and an area of 1 m^2, which housed up to 12 birds per box.

Characteristics of the Floor Surface

The perforated plastic floor used in the present study was identical to the one used for pig maternity floors. The plastic floor was composed of a washable material, with dimensions of 400 × 400 × 40 mm (length × width × height), each unit weighed 1.55 kg, and had a resistance up to 450 kg/m^2. The plastic floor was mounted on a wooden support, 0.5 m above the ground, to facilitate periodic scraping of waste. The wood shavings used were from a pine processing plant, and this nontoxic material was placed at a height of 5 cm for the poultry litter.

Removal of Waste and Poultry Litter Management

In the treatments with the plastic floor, waste was removed once during the first week, every other d from the beginning of wk 2, and daily from d 14 to d 42. The cleaning was performed by sweeping below the floor with a steel squeegee. The poultry litter (wood shavings) was turned and stirred frequently to provide greater incorporation of waste and prevent the formation of plaques.

Measurement of Ammonia and Carbon Dioxide

For monitoring NH_3 and carbon dioxide ($\mathbf{CO_2}$) concentrations, a Dräger Accuro® gas pump (Draeger, Houston, TX) coupled with colorimetric reagent tubes was used. The concentrations of the gases were measured in the center of climate chambers, at the birds' height, on d 28, 32, 35, 39, and 42.

Broilers' Performance

The birds and feed were weighed weekly, with weight gain (**WG**) (kg), feed intake (**FI**) (kg) and, subsequently, feed conversion (**FC**) determined. The evaluation of meat production (kg of meat for m^2) and viability (% of live chickens on d 42) was based on the methodology described by Oliveira et al. (2005).

Injuries Evaluation and Plumage Hygiene

For the evaluation of injuries, quality of locomotion and plumage hygiene, the Welfare Quality® Assessment Protocol for Poultry (Welfare Quality®, 2009) was used. This protocol consists of attributing scores for each factor by a trained appraiser at 42 d of bird's age. The number of birds evaluated was 6 per box (50%)

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Table 1. Diet composition percentage and calculated nutrient values of experimental broiler diets.

Ingredients(%)	Initial Phase*	Growth Phase**
Corn	60.81	63.74
Soy chaff 45%	35.15	29.79
Soy oil	–	3.12
Dicalcic phosphate	1.63	1.16
Limestone	0.84	0.76
Salt	0.42	0.44
L-Lysine HCL (78%)	0.25	0.21
DL-Methionine(99%)	0.29	0.23
L-Threonine	0.08	0.04
BHT	0.01	0.01
Vitamin and mineral supplement*	0.50	0.50
Total	100.00	100.00
	Calculated nutritional composition	
Crude protein (%)	21.27	18.86
Metabolizable energy (kcal/kg)	2.883	3.121
Ca (%)	0.85	0.69
Na (%)	0.19	0.20
Available phosphorus (%)	0.42	0.32
Methionine+ cysteine(digestible) (%)	0.88	0.77
Methionine (digestible). (%)	0.56	0.49
Lysine (digestible). (%)	1.22	1.05
Threonine (digestible). (%)	0.79	0.68
Tryptophan (digestible). (%)	0.24	0.21
Arginine (digestible). (%)	1.32	1.16

Nutrients per kilogram of diet: *From 1 to 21 d of—Vit. A, 7,000 IU; Vit. D3, 3,000 IU; Vit. E, 25 IU; Vit. K, 0.98 mg; Vit. B1, 1.78 mg; Vit. B2, 9.6 mg; Vit. B6, 3.5 mg; Vit. B12, 10 μg; Folic acid, 0.57 mg; Biotin, 0.16 mg; Niacin, 34.5 mg; Calcium pantothenate, 9.8 mg; Copper, 0.12 g; Cobalt, 0.02 mg; Iodine, 1.3 mg; Iron, 0.05 g; Manganese, 0.07 g; Zinc, 0.09 mg; Zinc oxide, 6.75 mg; Selenium, 0.27 mg; Choline, 0.4 g; Growth promoter (Zinc bacitracin), 30 mg; narasin + nicarbazin, 1 g; Methionine, 1.68 g. **From 22 to 42 d of age—Vit. A, 7,000 IU; Vit. D3, 3,000 IU; Vit. E, 25 IU; Vit. K, 0.98 mg; Vit. B1, 1.78 mg; Vit. B2, 9.6 mg; Vit. B6, 3.5 mg; Vit. B12, 10 μg; Folic acid, 0.57 mg; Biotin, 0.16 mg; Niacin, 34.5 mg; Calcium pantothenate, 9.8 mg; Copper, 0.12 g; Cobalt, 0.02 mg; Iodine, 1.3 mg; Iron, 0.05 g; Manganese, 0.07 g; Zinc, 0.09 mg; Zinc oxide, 6.75 mg; Selenium, 0.27 mg; Choline, 0.6 g; Growth Promoter (avilamycin), 7.5 mg; Monensin sodium, 0.1 g; Methionine, 1.4 g.

in a total of 48 males and 48 females per treatment, randomly selected.

Animals were visually inspected and scores were assigned for the presence or absence of breast blister, hock burn, and footpad dermatitis and, if present, the extent of injury in each bird. Plumage hygiene was recorded using a cleanliness score from 1 ("completely clean") to 4 ("completely wet or soiled with litter material, feces or dirt"), according to the amount of dirt impregnated in the breast and legs of each bird. For the quality of locomotion evaluation, birds were individually placed on the floor and stimulated to move approximately 10 steps and a gait score from 0 ("normal, dextrous and agile") to 5 ("incapable of walking") was given, according to the animal's ability to walk. All scoring systems used followed Welfare Quality® (2009).

Carcass Yield and Parts

For the analysis of hot carcass yield, all birds from each experimental box were weighed, and then the average weight was calculated to remove 3 birds per box (25% of the total number of birds housed) whose weight was close to the average ± 5% by weight average, with a total of 48 birds per treatment (50% males and 50% females). The birds were identified by enumerated plastic rings and subjected to eight hours of fasting in preparation for slaughter. The birds were desensitized with CO_2, followed by the procedures of bleeding, scalding, plucking, gutting, and cutting. The heavy parts measured were the chest, back, thigh + drumstick, and wing, in addition to the entire carcass. The carcass yield was based on the animal's weight after fasting and the weight of the clean carcass before cooling, whereas the yield of parts was based on the weight of the particular cut region by the weight of the clean carcass.

Statistical Analysis

The means of weight gain, feed intake, feed conversion, carcass and parts yield, meat production, and viability results were subjected to analysis of variance, using Tukey's test at 5% of probability using the SAS (Statistical Analysis System) program. For the NH_3 and CO_2 concentrations, graphics were produced with the concentration curves of these gases over the production cycles. For the scores of breast blister, hock burn, footpad dermatitis, cleanliness, and gait the analysis, their distributions per treatment and sex was used.

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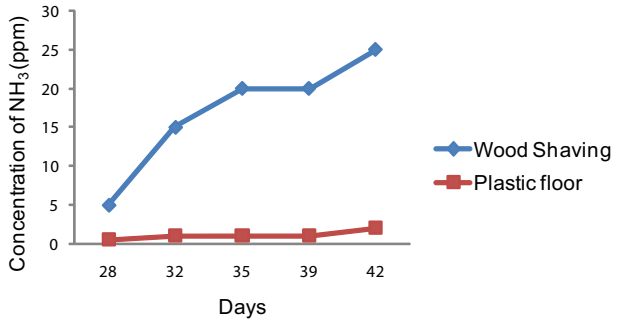


Figure 1. Ammonia concentration (ppm) under thermal comfort.

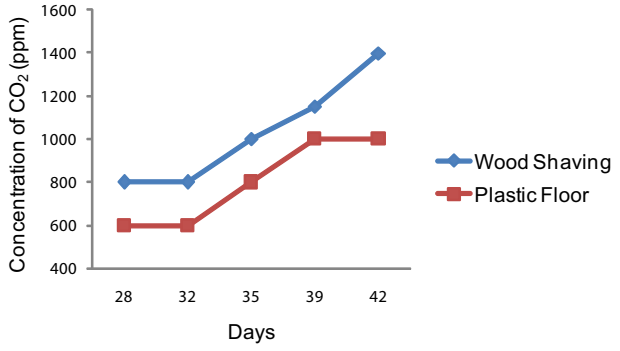


Figure 2. CO_2 concentration (ppm) under thermal comfort.

RESULTS

Concentration of Ammonia and Carbon Dioxide

The concentration of NH_3 from 28 to 42 d of age is shown in Figure 1. It was observed that the concentration of NH_3 increased significantly in the wood shavings treatment, with 5 ppm (28 d), increasing to 15 ppm on d 32, 20 ppm on d 35 and 39, and presenting the highest value on the d 42 (25 ppm). In the plastic floor treatment, the concentration of NH_3 gas remained almost zero, on the d 28 showed the lowest value (0.5 ppm), remained stable in 1 ppm on d 32, 35, and 39, and reaching a maximum value of 2 ppm on d 42. The CO_2 concentration also showed a gradual increase depending on the production d (Figure 2). In the wood shavings treatment, the lowest CO_2 concentration (800 ppm) was observed at the d 28 and 32, increasing to 1,000 ppm (35 d), 1,150 at 39 d, and reaching a maximum value of 1,400 ppm on d 42. In the plastic floor treatment the lower CO_2 concentration (600 ppm) was observed at the d 28 and 32, increasing to 800 ppm (35 d), and stabilizing in 1,000 ppm on d 39 and 42.

Performance

Broiler performance was measured by WG, FI, and FC (Table 2). Chickens reared on wood shavings (7 d) had a significant difference ($P < 0.01$) for FI between males and females. It was observed that males presented higher FI (0.186 kg) than females (0.174 kg). No significant difference ($P > 0.05$) was observed for WG, FI, and FC between males and females reared on plastic flooring.

On d 21, there was a significant difference ($P < 0.05$) between males and females for WG and FI in the wood shavings treatment, with males having higher WG (0.895 kg) than females (0.828 kg) as well as for FI, where males showed higher value (1.347 kg) than females (1.259 kg). It was not observed significant difference ($P > 0.05$) for FC. In the plastic floor treatment, there was a significant difference between males and females for WG ($P < 0.01$) and FI ($P < 0.05$), where males showed a higher WG (0.879 kg) than females (0.820 kg), as well as FI, where females showed lower value (1.270 kg) than males (1.340 kg). It was not observed significant difference ($P > 0.05$) between males and females for FC.

At the end of the production cycle (42 d) there was a significant difference ($P < 0.01$) for WG, FI, and FC between males and females reared on wood shavings as well as those reared on plastic flooring. In the wood shavings treatment, males showed higher WG (3.111 kg) than females (2.708 kg), as well as for FI, where males presented higher FI (5.082 kg) than females (4.665 kg). These values of WG and FI resulted into a better FC for males (1.63) than females (1.72). In the plastic floor treatment, males showed higher WG and FI (3.167/5.180 kg) than females (2.760/4.720 kg).

Table 2. Production performance of chickens raised in thermal comfort.

	Wood Shavings			Plastic Floor		
	Male	Female	*P*-value	Male	Female	*P*-value
Weight Gain 7 d (kg)	0.120 ± 0.002	0.121 ± 0.003	0.7804	0.117 ± 0.002	0.115 ± 0.001	0.1911
Feed Intake 7 d (kg)	0.186 ± 0.003 a	0.174 ± 0.002 b	0.0149	0.168 ± 0.003	0.163 ± 0.002	0.3487
Feed Conversion 7 d	1.55 ± 0.027 b	1.45 ± 0.040 a	0.0309	1.43 ± 0.032	1.42 ± 0.028	0.6735
Weight Gain 21 d (kg)	0.895 ± 0.015 a	0.828 ± 0.009 b	0.0219	0.879 ± 0.007 a	0.820 ± 0.003 b	0.0001
Feed Intake 21 d (kg)	1.347 ± 0.019 a	1.259 ± 0.013 b	0.0225	1.340 ± 0.017 b	1.270 ± 0.010 a	0.0015
Feed Conversion 21 d	1.51 ± 0.008	1.52 ± 0.008	0.3105	1.52 ± 0.012	1.54 ± 0.008	0.112
Weight Gain 42 d (kg)	3.111 ± 0.013 a	2.708 ± 0.046 b	0.0002	3.167 ± 0.013 a	2.760 ± 0.022 b	0.0001
Feed Intake 42 d (kg)	5.082 ± 0.041 a	4.665 ± 0.082 b	0.0038	5.18 ± 0.087 a	4.72 ± 0.053 b	0.0003
Feed Conversion 42 d	1.63 ± 0.008 a	1.72 ± 0.005 b	0.0001	1.64 ± 0.024 a	1.71 ± 0.007 b	0.0091
Viability (%)	94.14 ± 1.516	98.92 ± 2.254	0.1153	100.00 ± 0.000 a	94.05 ± 1.537 b	0.0082
Meat Production (kg/m^2)	35.922 ± 0.667 a	32.257 ± 0.827 b	0.0179	38.55 ± 0.162 a	31.64 ± 0.554 b	0.0001

Different lower case letters indicate significant differences in the column using Tukey's test at 5% significance.

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Table 3. Distributions (%) for the gait scores, injuries and cleanliness.

	Wood Shavings		Plastic Floor	
	Male	Female	Male	Female
Gait Score				
0	0.0	0.0	0.0	0.0
1	0.0	2.1	0.0	0.0
2	12.5	39.6	12.5	25.0
3	79.2	54.2	54.2	64.6
4	6.2	4.2	31.2	10.2
5	2.1	0.0	2.1	0.0
Hock Burn Score				
0	70.8	77.1	89.6	85.4
1	22.9	8.3	10.4	14.6
2	6.2	14.6	0.0	0.0
3	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0
Footpad Dermatitis Score				
0	75.0	58.3	68.7	50.0
1	10.4	27.1	14.6	20.8
2	12.5	14.6	14.6	22.9
3	2.1	0.0	0.0	6.3
4	0.0	0.0	2.1	0.0
Cleanliness Score				
0	2.1	2.1	2.1	2.1
1	37.5	37.5	72.9	41.6
2	35.4	37.5	25.0	56.2
3	25.0	22.9	0.0	0.0

The values of gait score vary from 0 (normal, dexterous and agile) to 5 (incapable of walking). Hock burn and footpad dermatitis scores range from 0 (absence of lesion) to 4 (severe damage). Cleanliness score ranges from 0 (completely clean) to 3 (completely wet or soiled with litter material, feces or dirt) (Welfare Quality, 2009).

Meat Production and Viability

On the wood shavings treatment, no significant difference ($P > 0.05$) was observed for viability between males (94.14%) and females (98.92%). However, males had higher ($P < 0.05$) meat production (35.922 kg/m^2) than females (32.257 kg/m^2).

For the plastic floor treatment, it was verified a significant difference ($P < 0.01$) for viability and meat production, where males showed higher viability (100%) than females (94.05%), and better meat production (38.55 kg/m^2) than females (31.640 kg/m^2).

Quality of Locomotion

With respect to the gait score distribution (Table 3), score 0 was not observed, and score 1 was found in only 2.1% of females in wood shavings. Males from both treatments had the same percentage of score 2 (12.5%), while for females, differences were found, with higher percentage (39.6%) of score 2 in the wood shavings treatment than in the plastic floor treatment (25%).

Score 3 was observed more frequently for males in wood shavings (79.2%) than for males in plastic floor (54.2%). By contrast, in females, 54.2% showed a gait score of 3 in wood shavings, compared to 64.6% in the plastic floor. The score 4 was observed with higher frequency in the plastic floor treatment for both males (31.25%) and females (10.40%) than for wood shavings treatment, which had a frequency of 6.20% and 4.16% for males and females, respectively. Score 5 was not observed among females in any treatment; among males this condition had a low occurrence (2.1%) and was evenly distributed between treatments.

Injury Scores

There were no animals affected by breast blister in any of the treatments. Most of the animals did not show footpad dermatitis either, especially among males, which had 75% of score 0 in the wood shavings, and 68.7% in the plastic floor treatment (Table 3). The percentages of scores 1 was higher for females from both treatments (27.1% *vs.* 20.8% for wood shavings and plastic floor, respectively), than for males (10.4% *vs.* 14.6% for wood shavings and plastic floor). In general, birds raised in plastic floors (males and females) had a greater tendency towards footpad dermatitis with score 2 or above than the birds reared on wood shavings.

With respect to hock burn, in both treatments the majority of the animals did not show any lesion, with a higher percentage of score 0 in plastic floor treatment than wood shavings, with approximately 90% of animals not affected. The score 2 was only found for wood shavings, in 6.2% of females and 14.6% of males, while scores 3 and 4 (severe conditions) did not occur in this study.

Plumage Hygiene

For the cleanliness score, few animals were completely clean, with 2.1% of score 0 for both treatments and sexes. Most of the animals assessed were scored as 1 or 2. A clear trend of worse hygiene conditions in wood shavings compared to plastic floor was found, for both sexes, since birds reared on wood shavings showed a lower frequency score of 1, which is considered suitable in the industry. Furthermore, approximately a quarter of the animals in this treatment was completely dirty (score 3), which is an undesirable score in the industry and was not found in any animal reared in plastic floor.

Carcass Yield and Parts

Males reared on wood shavings had a better live weight (3.069 kg) than females (2.650 kg), as well as eviscerated carcass weight (2.324 kg males vs. 1.987 kg females), chest weight (0.940 kg males vs. 0.819 kg females), thigh weight (0.647 kg males vs. 0.542 kg females), back weight (0.494 kg males vs. 0.421 kg females), and wing weight (0.229 kg males vs. 0.194 kg females) (Table 4). No significant difference ($P > 0.05$) was observed for relative weight (**RW**) between males and females in all analyzed parameters.

On the plastic floor, males showed a better live weight (3.225 kg) than females (2.730 kg), as well as eviscerated carcass weight (2.427 kg males vs. 2.062 kg females), chest weight (1.005 kg males vs. 0.855 kg

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Table 4. Absolute and relative carcass yield and parts.

	Wood Shavings			Plastic Floor		
	Male	Female	*P*-value	Male	Female	*P*-value
Live weight (kg)	3.069 ± 0.030 [a]	2.650 ± 0.030 [b]	0.0001	3.225 ± 0.028 [a]	2.730 ± 0.019 [b]	0.0001
Carcass weight eviscerated (kg)	2.324 ± 0.028 [a]	1.987 ± 0.021 [b]	0.0001	2.427 ± 0.022 [a]	2.062 ± 0.018 [b]	0.0001
RW of eviscerated carcass	0.757 ± 0.004	0.750 ± 0.003	0.1776	0.753 ± 0.005	0.755 ± 0.003	0.6622
Chest weight (kg)	0.940 ± 0.018 [a]	0.819 ± 0.014 [b]	0.0001	1.005 ± 0.013 [a]	0.855 ± 0.011 [b]	0.0001
RW of chest	0.404 ± 0.004	0.412 ± 0.005	0.2559	0.414 ± 0.004	0.415 ± 0.004	0.8873
Thigh weight (kg)	0.647 ± 0.007 [a]	0.542 ± 0.006 [b]	0.0001	0.672 ± 0.007 [a]	0.563 ± 0.008 [b]	0.0001
RW of thigh	0.279 ± 0.003	0.273 ± 0.002	0.1606	0.277 ± 0.003	0.273 ± 0.003	0.3820
Back weight (kg)	0.494 ± 0.007 [a]	0.421 ± 0.008 [b]	0.0001	0.510 ± 0.008 [a]	0.436 ± 0.006 [b]	0.0001
RW of back	0.213 ± 0.002	0.212 ± 0.003	0.8306	0.210 ± 0.002	0.212 ± 0.002	0.5325
Wing weight (kg)	0.229 ± 0.003 [a]	0.194 ± 0.002 [b]	0.0001	0.234 ± 0.003 [a]	0.198 ± 0.003 [b]	0.0001
RW of wing	0.099 ± 0.001	0.098 ± 0.001	0.6073	0.097 ± 0.001	0.096 ± 0.001	0.6119

RW = Relative weight (%)
Different lower case letters indicate significant differences in the column using Tukey's test at 5% significance.

females), thigh weight (0.672 kg males vs. 0.563 kg females), back weight (0.510 kg males vs. 0.436 kg females), and wing weight (0.234 kg males vs. 0.198 kg females). No significant difference ($P > 0.05$) was found for RW between males and females in all analyzed parameters.

DISCUSSION

The environmental conditions in the poultry facilities are as important to the animals being raised as to the farm workers. The NH_3 measured in the air on the wood shavings treatment at 42 d of age reached a higher concentration (25 ppm) than the recommended by the GLOBAL G.A.P (2016), which is the main program of farm quality assurance in the world. This program states that the concentration of NH_3 in the air from the production environment must not exceed 20 ppm. Carvalho et al. (2011) found NH_3 concentrations near 60 ppm when studying the influence of poultry litter quality in the environment in broilers sheds. They reported that this high concentration of NH_3 in the atmosphere was owing to the reuse of poultry litter, which led to a further degradation of nitrogen compounds in the litter material and hence an increased release of NH_3 into the production environment. Traldi et al. (2007) also observed a greater potential of NH_3 volatilization in reused poultry litter than in new poultry litter. According to Bianchi (2013), high concentrations of NH_3 reduce the comfort of animals and cause problems for their health, affect the durability of installations, and reduce the safety and efficiency of the production process.

According to the Brazilian regulation of workers safety, the Standard Regulatory 15-Activities and unhealthy operations (MTE, 2008), tolerable NH_3 concentrations for humans is 20 ppm, with tolerated exposure up to 8 h daily. However, Carvalho et al. (2012) showed that when the NH_3 concentration is above 10 ppm, the feeling of irritation appears in the eyes and nostrils, and recommended the use of masks throughout the management period within the poultry farm. In the present study, the concentration of NH_3 appeared to be outside the tolerable range for humans, indicating an unsanitary situation for workers when wood shavings are used as the bedding material. However, low production of NH_3 obtained in the plastic floor treatment is an extremely important outcome, as NH_3 was not produced in high concentrations within the chambers having perforated plastic floors, leading to less detrimental effects to animals and people living and working in the poultry facility.

Concerning the CO_2 concentration, an increase in the CO_2 in the atmosphere was observed in accordance with the broiler's growth, a result that concurs with the findings of Henn et. al. (2015) that observed CO_2 emissions are proportional to live weight, and their rates are proportional to weight gain. The concentration of CO_2 in the atmosphere with wood shavings was always higher than that observed in the environment with plastic floors, caused by the microbial degradation process of organic matter accumulated in the wood shavings (Henn, 2013). Orrico Jr et al. (2010) noted that the majority of the organic matter in poultry litter is lost as water and CO_2. In the present study, even in the wood shavings treatments, CO_2 concentrations remained within the optimal range, which according to GLOBAL G.A.P (2016) is 5,000 ppm for broilers, with values above this representing a risk for animals. Henn (2013) also observed levels (1,260 ppm) below the critical threshold of CO_2 concentration in his study about broiler chickens raised in poultry houses when utilizing new wood shavings.

The data of this study showed that, as expected, males showed better performance than females, with higher WG, FI, and better FC, for both treatments. A similar result was obtained by Andrews et al. (1990), who studied the performance of broiler chickens on different surface materials, and observed higher WG in males than in females. We also observed that broilers reared on plastic floor treatment had WG and FI relatively higher than observed for chickens reared on wood shavings treatment. It was verified that males reared on plastic floor were 56 g heavier than males raised on

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wood shavings; as well females reared on plastic floor were 52 g heavier than females raised on wood shavings treatment. These results could be very important in a practical and economic view. Males reared on plastic floor showed a meat production 2.628 kg/m^2 higher than males reared on wood shavings; this data is very important due the fact of being an expressive value. If we consider poultry shed with 1,200 m^2, we would have an increase of 3,153 kg of chicken meat, taking into consideration the total production area of broilers worldwide, which represents an extra financial gain for the producer. There was no significant difference in viability between males and females reared on wood shavings, but males reared on plastic floor showed higher viability (100%) than females (94.04%). The larger viability of males reared on plastic floor than males reared on wood shavings can be collaborating with the higher meat production of males reared in this system.

The results obtained regarding breast blister were similar to those obtained by Garcia et al. (2012), who observed no incidence of breast injury when evaluating different types of materials (wood shavings, rice husks, chopped napier grass) that might be used for poultry litter. Oliveira et al. (2002) also observed no effect of bedding material on breast lesions in broilers when studying 2 different types of poultry litter (wood shavings and sawdust). For footpad dermatitis, our results differ from those obtained by Kacher et al. (2013), who compared the effect of plastic flooring and wood shavings in duck production and showed lower frequency of footpad dermatitis in animals raised on plastic floors than in animals reared on wood shavings. In the present study, the severe condition of footpad dermatitis (score 4) had low occurrence, and only in plastic flour treatment. Additionally, plastic floor showed lower frequency of animals (males and females) without footpad lesions, compared to wood shavings treatment.

Regarding hock lesions, a possible cause of higher incidence of this type of injury in birds reared on wood shavings may be owing to the type of material used, which is more abrasive than plastic floors that have a smoother surface. Oliveira et al. (2002) studied the effect of using 2 different kinds of materials for poultry litter (sawdust and wood shavings) and showed that at a density of 10 birds/m^2, the type of floor material did not have any effect on the footpad and hock damage, while the birds with density of 14/m^2 had a higher incidence of hock and footpad lesions to birds raised on sawdust than birds rearing on the wood shavings.

The plastic floor management could be very important for broilers hygiene. In the present study, the presence of a plastic floor improved the plumage hygiene, once the broilers had a lower contact with feces. A better hygienic situation in ducks reared on plastic floors than on conventional litter was found by Karcheret al. (2013). Akpobome and Fanguy (1992) studying broilers on different types of poultry litter, also observed better results with cleaning of the broiler feathers for those poultry reared on plastic floors than for those reared on wood shavings.

For gait score, there was no incidence of scores 0 and 1, that was associated with a very good locomotor quality and absence of walking disability. Most of the animals received scores 2 or 3, which was expected due to the rapid growth in broiler chicken lines. Animals displaying gait score 2 had an abnormality in their gait; however, their ability to walk was not severely compromised, being considered a moderate condition, whereas, the scores 3 or above are conditions that must be considered important welfare issues, since animals have the ability to walk compromised (Knowles et al., 2008; de Jong et al., 2014, 2016). In the present study, higher frequency of gait score 3 or above was found for plastic floor, indicating that animals in this treatment tended to have more locomotor problems than those raised on the conventional litter (wood shavings).

A plausible cause for these findings is the low absorption of impacts on this type of floor material, and low adherence of animals to the surface. When wood shavings are utilized, the animals are on a soft substrate that is capable of absorbing impact and gives more support to the animal, promoting better development of the locomotor system (Lensink et. al., 2013). Another possible explanation is the greater weight of the birds, since according to Nääs et al. (2010), the limited mobility of broilers is directly linked to the weight of the animal, where heavier animals tend to show higher incidence of locomotor issues than lighter animals. Fernandes et al. (2012) observed a proportionality between the degree of difficulty of movement and the weight of the animals, where animals with higher locomotion scores (greater difficulty in locomotion) showed a weight numerically greater than animals with less limited mobility.

CONCLUSION

The findings of this study suggest that perforated plastic floors could be a good alternative to substitute wood shavings to raise broilers (male and female) since it was efficient from the perspective of environmental conditions and production rates, promoting a better quality environment and superior production rates. However, more research must be conducted to study the effects of perforated plastic floors on poultry welfare, aiming to improve leg health, reduce footpad dermatitis and lameness of animals reared in this system.

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