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Effect of Litter Substrates on the Performance, Carcass Traits, and Environmental Comfort of Red-Winged Tinamou (Rhynchotus Rufescens)

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ABSTRACT

The study aimed at evaluating the effect of litter substrates on the performance, carcass traits, and environmental comfort of red-winged tinamou (*Rhynchotus rufescens*). In this experiment, 160 birds, with 100 and 300 days of age, were housed into 20 pens, and distributed according to a completely randomized experimental design into five treatments with four replicates of eight birds each. Treatments consisted of five litter substrates: wood shavings, rice husks, peanut hulls, grass hay, or sand. Feed intake; weight gain; breast, hock, and footpad lesions; back feathering; total meat production; carcass and parts yield; and leukocyte counts were evaluated. Litter substrates were analyzed for dry matter content, standard microbial count, ammonia volatilization potential, water content, water holding capacity, temperature, and radiant heat load. The results showed that litter substrate did not influence the evaluated bird parameters, despite the higher microbial counts and released ammonia values determined in peanut hulls and sand, respectively. Sand also tended to have higher average temperature than the other litter substrates. It was concluded that litter substrate should be chosen at farmer discretion, taking into consideration its cost and utilization after use.

INTRODUCTION

The increasing global demand of poultry meat has posed increasing challenges to producers, who try to balance financial returns with environmental protection and animal welfare. In this context, poultry-house litter has an important role, as it is closely linked both to bird welfare during rearing and to product quality.

Litter is defined as the substrate spread on the poultry house floor to serve as bedding (Paganini *et al.*, 2004), and aims at preventing direct contact of the birds with the floor, absorbing water and waste, collecting feathers, and minimizing sudden temperature changes inside the poultry house, thereby providing comfort to the birds (Garcia *et al.*, 2013). Litter is also related to flock health status. Because it receives all bird excreta, it has high microbial loads, and therefore, may be a contamination source, spreading and perpetuating disease in the rearing facilities.

As the birds are constantly in contact with the litter, substrates need to present specific quality characteristics in order to provide good rearing environment quality and comfort to the birds. Therefore, when choosing litter substrates, the following characteristics should be taken into account: low cost and high availability, cushioning capacity, low thermal conductivity, easy evaporation of the absorbed water, and intermediate particle size (Ávila *et al.*, 1992). It needs to dry fast, be soft and comfortable to the birds, and provide minimum environmental humidity absorption (Ângelo *et al.*, 1997).

Litter moisture also strongly influences the incidence and severity of carcass lesions, as well as provides a favorable environment for the replication of microorganisms that may contaminate the birds' skin. Litter moisture is influenced by bird rearing density, litter substrate, drinker type, bird health status, etc. Wet litter may induce severe ulcerations, particularly in the footpad and breast of commercial broilers due to caking.

Wood shavings is a byproduct of lumbering with approximately 3-cm particle size, and has good water holding capacity, which, however, depends on wood type. It is commonly available in lumbering and reforesting areas (Ávila *et al*., 1992).

Grass hay, particularly of coast-cross grass, *Brachiaria*, buffalograss, Rhodes grass, molasses grass, and other grasses used for grazing, when adequately manufactured, has low production cost and high production volume. Dry grass hay has good moisture absorption capacity and provides comfort to the birds due to its excellent cushioning capacity (Rosa *et al*., 2007).

Peanut hulls have good water holding capacity, compressibility, and homogeneity; however, when excessively wet, may be contaminated with *Aspergillus flavus* or *Aspergillus fumigatos*, causing aspergillosis in poultry (Neme *et al*., 2000).

Rice husks are residues of rice processing. Their use should be limited due to their low water holding capacity and very small particle size, and may pose intoxication risks as they may be ingested by the birds.

Several studies have demonstrated that sand can be used as litter substrate in poultry production. According to Bowers *et al*. (2003), sand has two main advantages: it may be reutilized for up to 20 flocks and it is easy to clean, minimizing the time and labor required to prepare the poultry house for the placement of day-old chicks. Macklin *et al*. (2005) also showed that sand litter has low bacterial counts and low moisture levels, suggesting lower health risks. In addition, this litter substrate also causes less leg damage.

Therefore, the objective of the present study was to evaluate performance, carcass, and environmental comfort characteristics of red-winged tinamous reared on different litter substrates.

MATERIALS AND METHODS

The experiment was conducted in the Wild Animal Sector of the Department of Animal Science of the School of Agricultural and Veterinary Sciences of UNESP, Jaboticabal campus, SP, Brazil. Red-winged tinamous (*Rhynchotus rufescens*) were housed in a conventional masonry broiler house with concrete floor and tin roof. The open sides of the house were provided with blue plastic curtains that were mechanically opened or closed according to the weather in order to protect the birds against rain and strong drafts. The house was internally divided in pens (2.0m x 1.0m x 2.1m) separated by wire mesh. The concrete pen floor was covered with the evaluated litter substrates. A pelleted feed based on corn and soybeans was formulated to contain 28% crude protein and 2800 kcal metabolizable energy/kg, according to Moro (1996). Feed was supplied in tube feeders *ad libitum* during the entire experimental period. Water was offered *ad libitum* in bell drinkers.

One hundred and sixty growing red-winged tinamous, with initial ages from 100 to 300 days, were reared in 20 pens for 60 days. Birds were distributed according to a completely randomized experimental design, consisting of five treatments with four replicates (pens) of eight birds each. Treatments consisted of five litter substrates: wood shavings, rice husks, peanut hulls, coast-cross grass (*Cynodon dactylon*) hay, or sand. The following parameters were evaluated: feed intake; weight gain; total meat production (TMP); carcass and parts yield; breast, hock, and footpad lesions; back feathering; and leukocyte counts were evaluated. Litter substrates were evaluated for dry matter content, standard microbial count, ammonia volatilization potential, water content, water holding capacity, temperature, and density.

Feeders were filled and weighed weekly to determine feed intake.

Birds were weighed once weekly, starting in the first experimental week, to calculate average weekly weight gain. Feather coverage on the back of the birds was visually scored at the time of weighing according to a 1-4 scale: 1 = skin was not visible, 2 = small featherless spots, 3 = large featherless areas, and 4 = the back skin was fully exposed.

At the end of the trial, birds were weighed to calculate total meat production, that is, the amount of meat produced in grams per floor area, according to the equation TMP = TW/A, where TMP = total meat production (g/m^2); TW = total weight of the birds in the flock (g); and A = pen area (m^2).

Carcass and parts yield was determined in eight birds per treatment, totaling 40 birds. Birds were feed-fasted for 12 hours before sacrifice. On the day of slaughter, two males per pen were randomly selected, identified, and weighed to determine slaughter weight, which was used as reference for the calculation of carcass and cuts yield. During the evisceration step, two evaluators scored breast, hock, and footpad lesions according to the 0-5 scale proposed by Ângelo *et al*. (1997) as: 0 = no lesions; 1 = ulceration with few inflammation points; 2 = ulceration with mild inflammation; 3 = ulceration with intermediate inflammation; 4 = ulceration with severe inflammation; and 5 = very severe lesion.

Carcasses were then chilled, dripped, and cutup to obtain the following parts: head with neck, wings, breast, back, and legs (thighs and drumsticks). Parts were individually weighed.

Total leukocyte count values and differential leukocyte count values (including lymphocyte, heterophil, eosinophil, monocyte, and basophil counts) relative to total leukocyte count were determined at the end of the experiment. One bird per pen was selected, and its blood was immediately collected in ethylenediamine tetra-acetic acid (EDTA, 10mg/mL) by brachial vein puncture using a 3mL disposable syringe fitted with a 0.45x13 needle. A drop of blood was smeared on a previously cleaned slide using a cover slip, and immediately fixed. Two blood smears were processed per experimental unit. Blood smears were then submitted to the veterinary clinical pathology laboratory of GLN Veterinary Hospital of FCAV/UNESP, where they were stained using a panoptic kit. In total, 100 leukocytes, including granulocytes (heterophils, eosinophils, and basophils) and agranulocytes (lymphocytes and monocytes) were counted in each blood smear under a conventional binocular light microscope at 100x and 10x magnitudes. Total leukocyte counts were carried out with the aid of a dilution module (DA500), and an automatic counter (CC510), both from the company CELM (Companhia Equipadora de Laboratórios Modernos S.A., Brazil).

Six litter samples were collected per pen at the end of the experiment to determine ammonia content, dry matter content, density, water holding capacity, and microbial counts.

Ammonia released from the litter was determined according to the methodology described by Hernandez *et al*. (2001). Dry matter content was determined according to the methodology of Silva (1990).

Water holding capacity was calculated based on dry matter percentage of each litter substrate per replicate, as follows: a 50g sample of each litter was collected, and dry matter percentage was determined. Samples were then placed in a 500mL beaker and water was added to full beaker capacity. The mixture rested for 30 minutes, after which the water was drained using a fine-mesh sieve for 3 min, and the sample was weighed. The amount of water absorbed, in g, was calculated as the difference between sample final and initial weights. Litter density was determined as the litter weight needed to fill a 1L recipient.

Standard microbial count was performed according to the methodology described by Lanara (1981).

Data relative to the internal thermal environment of the broiler house were collected once weekly, in the morning (10:00 AM) and in the afternoon (4:00 PM), for eight weeks. Black globe-humidity index (BGHI) and radiation thermal load (RHL) were calculated according to the equations of Buffington *et al*. (1981) and Esmay (1979), respectively, using a black globe set in the middle of the pen. Litter surface temperature (LT) was measured using an infrared thermometer, whereas litter internal and bottom temperatures were measured using a probe connected to the infrared thermometer.

Quantitative parameters, such as feed intake, weight gain, total meat production, carcass and parts yield, leukocyte counts, and litter parameters were submitted to analysis of variance using the least square method. In addition to the effect of treatments (5), the effect of age class was included in the model as a covariate. Treatments means were compared by the test of Duncan ($p = 0.05$).

The effect of litter substrate on feathering and lesion scores was analyzed by the Chi-square test at 5% significance level.

The environmental parameters BGHI, RHL, and LT were analyzed according to a completely randomized experimental design comprising five treatments (litter substrates) with four replicates in a split-plot design, testing the factor treatment in the plots and the factor age (two levels) in the subplots. Measures were repeated for eight weeks. Means were compared by the test of Duncan at 5% significance level.

All statistical analyses were performed using SAS statistical software (SAS 9.1, SAS Institute, NC, USA).

Economic viability assessment was based only on the price and amount of litter substrate required to obtain a 6cm high litter, as all the other parameters were constant in the different treatments. The applied litter substrate volumes and prices were: 20 bales of coast-cross grass (*Cynodon dactylon*) hay at R$8.00

per bale; 2 m^3 of coarse sand at R$75.00 per cubic meter; forty bags of rice husks at R$3.00 per bag; 40 bags of wood shavings at R$7.00 per bag; and 40 bags of peanut hulls at R$5.00 per bag.

RESULTS AND DISCUSSION

There was no influence of litter substrate ($p>0.05$) on weight gain and feed intake measured on d 30 and 60, neither on total meat production (Table 1). These results suggest that rice husks, wood shavings, peanut hulls, grass hay, and sand are technically viable and equivalent when used as litter substrate for red-winged tinamous. The effect of age was significant ($p<0.05$) on all traits, except for feed intake on d 60.

Studies evaluating different litter substrates for broilers obtained similar results. Garcia *et al*. (2013) did not find any differences in the weight gain or feed conversion ratio of broilers reared on Napier grass, rice straw, wood shavings, or sugarcane bagasse. Sorbara *et al*. (2000) also did not observe any effect of pelleted citrus pulp litter on broiler performance. Santos *et al*. (2000a,b) evaluated four litter substrates (wood chips, rice husks, chopped corn cobs, and coffee hulls) and did not detect any differences in broiler weight gain, feed intake, or feed conversion ratio.

In addition, there was no influence of treatments ($p>0.05$) on carcass yield, water absorption in the chiller, fasting weight loss, or leg, breast, wing, or back yields (Table 2). Comparable results were obtained by Ângelo *et al*. (1997) and Willis *et al*. (1997), who did not observe any effect of different litter substrates on the slaughter weight or carcass yield of broilers. Garcia *et al*. (2013) did not find any effect of litter substrate on slaughter weight and carcass yield of broilers either.

Interestingly, high average carcass yield (87.41 ± 0.41%) was obtained in the present experiment. Moro *et al*. (2006) reported a lower value, of 74.4%, in red-winged tinamous (*Rhynchotus rufescens*) submitted to different feeding programs, whereas Queiroz *et al*. (2013), evaluating rearing density, obtained 85.48% average carcass yield in this same species.

On the other hand, bird age significantly affected ($p<0.05$) carcass yield, breast yield, and back yield. The average breast yield obtained in the present experiment was 31.79 (± 0.29) %; which is lower than those reported by Queiroz *et al.* (2013) and Moro *et al*. (2006), of 33.72% e 36.6%, respectively. The effect of age on breast yield is an indication that the growth of the breast muscles is associated with secondary sexual differentiation of flightless birds.

Total meat production (TMP), in g/m^2, was also influenced by bird age ($p<0.05$). The coefficient of linear regression of age on TMP was significant and equal to 155.68 g/m^2, showing that older birds, and therefore, heavier at the beginning of the experiment, presented higher TMP averages. This result is consistent with the other findings of the present study. As there was no significant effect of the treatments on performance parameters (WWG and feed intake), it was expected that older, and therefore, heavier birds produced a higher amount of meat per rearing area.

No breast, hock, or footpad lesions were observed in any of the birds, i.e., all birds were scored 0 for lesions in these areas during processing. This was expected because of the low bird density in each pen, which allowed bird movement and did not result in large excreta production, which would have caused litter moisture and caking, and therefore, higher probability of lesions. It must be noted, however, that applying higher bird rearing density could have compromised the experiment due to agonistic interactions among birds because red-winged tinamou is a non-domesticated species (Cromberg *et al*., 2007).

Under the conditions of this experiment, there was no influence of treatments ($p>0.05$) on blood leukocyte counts (Table 3).

Table 1 – Mean and standard error (between parentheses) of the traits average weekly weight gain (WWG), feed intake on day 30 (FI30) and on day 60 (FI60), and total meat production (TMP) of red-winged tinamous reared on different litter substrates.

Treatments	WWG (g)	FI30 (g)	FI60 (g)	TMP (g/m^2)
Wood shavings	14.17 (2.89)	1170.38 (47.00)	2696.46 (90.34)	1803.40 (167.47)
Grass hay	16.00 (3.40)	1240.16 (122.64)	2726.10 (234.19)	1954.70 (76.34)
Sand	14.13 (4.30)	1228.13 (74.63)	2711.40 (146.42)	1801.90 (121.72)
Peanut hulls	15.84 (4.19)	1018.44 (24.17)	2362.20 (86.54)	1737.10 (102.04)
Rice husks	15.52 (4.97)	1114.13 (24.02)	2548.70 (98.69)	1838.00 (131.77)

Means were not different by the test of Duncan ($p>0.05$).

Table 2 – Mean and standard error (values between parentheses) of the traits water absorption in the chiller (WAC), carcass yield (CY), leg yield (LY), breast yield (BY), wing yield (WY), back yield (BcY), and fasting weight loss (FWL) of red-winged tinamou reared on different litter substrates.

Treatments	WAC (g)	CY (%)	LY (%)	BY (%)	WY (%)	BcY (%)	FWL (g)
Wood shavings	41.88 (3.58)	88.13 (1.06)	24.72 (0.60)	31.87 (0.41)	13.22 (0.39)	24.33 (0.58)	26.00 (1.41)
Grass hay	43.13 (2.86)	86.73 (0.79)	24.15 (0.53)	31.66 (0.58)	13.65 (0.83)	25.13 (0.73)	27.00 (2.93)
Sand	53.38 (5.62)	86.44 (0.76)	24.71 (0.53)	30.88 (0.82)	13.59 (0.26)	24.53 (0.49)	26.75 (1.31)
Peanut hulls	44.63 (5.43)	88.59 (0.57)	24.51 (0.52)	32.80 (0.58)	13.42 (0.41)	24.18 (0.71)	26.25 (2.81)
Rice husks	44.25 (3.99)	87.16 (1.24)	24.61 (0.43)	31.73 (0.77)	13.61 (0.33)	24.88 (0.47)	36.25 (9.89)

Means were not different by the test of Duncan ($p>0.05$).

Leukocytes are the basis of the immune system of vertebrate animals, and their main function is the protection against pathogens, toxins, neoplasia, as well as self-aggression phenomena. Immune cells and molecules act both in primary immune defense (innate, non-specific immunity) and in secondary immune defense (adaptive or specific immunity) mechanisms.

Heterophils are responsible for the defense against bacteria, whereas eosinophils act during hypersensitization reactions, including those caused by parasites, such as intestinal worms and protozoa. The role of basophils in poultry is not fully elucidated, but is seems to be an immune mediator at the beginning of the inflammatory response. Lymphocytes aid the recognition and destruction of many types of pathogens and produce immunoglobulins. B-lymphocytes, which are differentiated into plasmocytes, and monocytes, which mature to become tissue macrophages, are essential for the defense against intracellular pathogens, such as viruses and some bacteria (Maxwell, 1993).

In most bird species, lymphocytes are predominant in differential leukocyte counts, accounting for 40-70% of total leukocyte count, followed by heterophils in healthy individuals. However, as shown in Table 3, red-winged tinamous *(Rhynchotus rufescens)* presented a higher percentage of heterophils (H) relative to lymphocytes (L). The same H/L ratio is also found in ostriches and pheasants (Charles-Noriega, 2000). According to Garcia-Navarro & Pachaly (1994), chronic stress conditions, such as long captivity periods and poor management conditions, may substantially change blood values, particularly chronic high blood cortisol levels. In addition to stress, several other factors affect the hematological balance, leading to changes in blood cell shape, size, and number.

Gross & Siegel (1983) proposed that the H/L ratio could be used as an indication of physiological changes, whereas blood corticosterone level is affected before physiological alterations occur. Therefore, the H/L ratio is an indication of long-term changes, and blood corticosterone level, of short-term changes. Those authors also suggested that H/L ratios of approximately 0.2, 0.5, and 0.8 indicate low, intermediate, and high stress levels, respectively. El-Lethey *et al.* (2003) compared a group of chickens reared on floor pens with foraging material with another group reared in naked

Table 3 – Mean and standard error (values between parentheses) of the absolute (ALC) and differential leukocyte counts (as a % of ALC) of red-winged tinamou reared on different litter substrates.

Treatments	Basophils (%)	Eosinophils (%)	Heterophils (%)	Lymphocytes (%)	Monocytes (%)	ALC (µL)
Wood shavings	1.09 (0.39)	1.83 (0.91)	45.75 (5.40)	45.42 (7.28)	2.09 (0.94)	12000.00 (3899.68)
Grass hay	0.75 (0.44)	2.17 (1.52)	47.92 (5.73)	46.33 (5.17)	2.83 (1.43)	8500.00 (957.43)
Sand	0.83 (0.21)	1.67 (0.53)	52.00 (5.07)	41.50 (4.94)	3.67 (0.71)	16333.33 (7969.85)
Peanut hulls	0.67 (0.24)	2.42 (0.76)	58.58 (4.61)	35.00 (4.55)	3.25 (0.64)	12833.33 (5729.23)
Rice husks	1.25 (0.42)	1.75 (0.50)	48.50 (3.97)	44.42 (4.83)	3.83 (0.50)	9083.34 (2719.53)

Means were not different by the test of Duncan ($p>0.05$).

cages and found higher H/L ratios in caged-reared chickens. Hata (2009) determined a 0.5116±0.2580 H/L ratio in 139 red-winged tinamou.

In the present study, H/L ratios determined in birds reared on all evaluated litter substrates were higher than one, indicating high stress level, suggesting that the red-winged tinamou is still not adapted to captivity. However, wild-bird hematology has not been extensively researched, and therefore, further studies are needed to establish reference values in order to further understand and interpret their hematology values in terms of health status.

Released ammonia, microbial counts, dry matter content, litter density, and water holding capacity were significantly different ($p<0.01$) among the evaluated litter substrates. Sand presented the highest released ammonia content, i.e., its nitrogen retention potential was the lowest among litter substrates, followed by rice husks, which released ammonia level was higher than that of wood shavings, grass hay, and peanut hulls, which were not different from each other ($p>0.05$), as shown in Table 4.

Ammonia is a gas produced by the microbial breakdown of uric acid eliminated in bird excreta. Excessive moisture and temperature may increase its production in the litter. Some of the negative effects of ammonia are poor growth rate and feed conversion ratio (Moore *et al*., 1996). In the present experiment, no significant differences in released ammonia level were detected among peanut hulls, grass hay, and wood shavings. This result is in agreement with the findings of Benabdeljelil & Ayachi (1996), who detected similar released ammonia levels in wood-shavings, sawdust, and peanut-hull litters. On the other hand, Lien *et al*. (1998) found lower released ammonia levels in wood-shavings litter (1.173 ppm) compared with peanut-hull litter (1.551 ppm).

In the present trial, sand presented the highest dry matter content and released ammonia levels, differently from Koerkamp *et al*. (1999), who found a significant linear correlation between ammonia volatilization and litter moisture content.

High levels of ammonia volatilization indicate high microbial populations, which produce high levels of urease (Fenn *et al*., 1987). In the current trial, however, no positive linear relationship between microbial counts and released ammonia levels was found. The highest microbial count was obtained in peanut hulls, which was significantly different ($p<0.05$) from the other litter substrates evaluated, which in turn were not different in terms of colony-forming units. Peanut hulls may also favor the proliferation of molds, thereby contributing to higher microbial counts. According to Neme *et al*. (2000), peanut hulls present good water holding capacity, compressibility, and homogeneity; however, when excessively wet, it may be contaminated with *Aspergillus flavus* and *Aspergillus fumigatos*, causing aspergillosis in poultry.

Density was significantly different ($p<0.05$) among treatments (Table 4). Sand presented the highest density because its particles are heavier and denser compared with the other substrates. Grass hay had the lowest density due to its light and dry nature. Santos *et al*. (2005) compared different litter substrates (wood chips, rice husks, chopped corncobs, and coffee hulls), and observed higher density in coffee hulls. Therefore, litter density is affected by substrate particle size.

Water holding capacity was significantly different ($p<0.05$) among substrates, with sand presenting the lowest values (Table 4). Wood shavings, rice husks, and peanut hulls presented similar ($p>0.05$) water holding capacity, and grass hay was not different from wood-shavings ($p>0.05$; Table 4).

Table 4 – Mean and standard error (values between parentheses) of released ammonia levels, colony-forming units (CFU), dry matter content (DM), water holding capacity (WHC), and density (DENS) of the evaluated litter substrates.

Treatments	Ammonia (g /100g of incubated substrate)	CFU/g	DM (%)	WHC (g)	DENS (g)
Wood shavings	0.95c (0.15)	104575.10^4b (6001060015)	91.30b (1.07)	103.71ab (11.70)	72.01c (0.00)
Grass hay	1.04bc (0.24)	$744475.\ 10^3$b (399895456)	89.28c (0.59)	84.61b (8.24)	56.15e (0.00)
Sand	3.76a (0.34)	453875.10^3b (190279441)	99.31a (0.05)	5.10c (1.36)	1309.12a (0.00)
Peanut hulls	1.13bc (0.14)	23725.10^5a (513527425)	90.05bc (0.10)	116.06a (8.30)	60.78d (0.00)
Rice husks	1.75b (0.33)	71675.10^4b (180256010)	90.91b (0.09)	128.20a (9.57)	103.39b (0.00)

Means followed by equal letters were not different by the test of Duncan ($p>0.05$).

High water holding capacity causes litter caking, i.e., a high volume of substrate occupies a same area, making air passage among particles more difficult, and therefore, hindering water evaporation, as demonstrated by Pearson *et al*. (2000) and Rehbeger (2002). On the other hand, Santos *et al*. (2000a) verified that litter substrates with small particle size were drier (69%) than those with larger particles (64%), as also found in the present study, where sand presented the lowest WHC.

Sand presented the highest dry matter content (99.31 ± 0.05%; $p<0.05$) compared with the other litter substrates (Table 4). The average dry matter content of all substrates was high (92.17 ± 0.60%) because of the low bird density in the pens and consequently, of low excreta production. Macklin *et al*. (2005) evaluated sand and pine chips as litter material and did not find any microbial count differences, despite the lower moisture content of sand. Santos *et al*. (2005) concluded that litter substrates with small particle size and high density, allowing the placement of shallow litters, promoted good 42-d-old broiler performance.

Another consideration when using different litter substrates for the production of red-winged tinamous is litter ingestion. Birds may voluntarily ingest litter substrate, if it is palatable, or involuntarily, when the birds consume feed wasted on the litter. In this context, Momo (2007) reported a high incidence of intestinal tract lesions and perforations in red-winged tinamous reared on grass hay litter due the presence of foreign bodies and grass stems. Ávila *et al*. (2008) studied several litter substrates for broilers (wood shavings, rice husks, chopped corncobs, chopped elephant grass, chopped soybean stubble, chopped corn stubble, and sawdust) and found significant intestinal lesion score differences among substrates and flocks. The highest number of lesions was detected in broilers reared on sawdust and the lowest, on elephant grass litter.

In the present study, feathering scores were not different ($p>0.05$) among treatments. However, the most frequent scores (mode) were: 3 for wood shavings and peanut hulls, 1 for grass hay, 4 for sand, and 2 for rice husks.

Sugui (2007) observed significant feathering differences when evaluating red-winged tinamou rearing density, and verified that increasing bird density per m^2 tended to intensify feathering problems. However, poor feathering seemed to be more related with feather pecking than with feather growth. Feather pecking is very frequently observed in layers and turkeys, and its main causes are nutrient deficiencies, excessive light (both in terms of intensity and period), low drinker and feeder availability, pelleted feed, high bird density, excessive heat during brooding, deficient ventilation, low humidity, and poor litter quality (Jaenisch *et al*., 2004).

The evaluated bioclimatic indexes (RHL and BGHI) were influenced only by the period of the day, possibly because air temperature tends to be hotter in the afternoon. Average BGHI index values as a function of period of the day and litter substrate were within the comfort range. Teixeira (1983) observed that BGHI indexes of up to 77 do not affect layer performance. The average RHL values were also within the comfort zone, which upper limit, according to Rosa (1984), is 498.3 W m^{-2}.

Litter surface, internal, and bottom temperatures were statistically similar ($p>0.05$) among litter substrates, suggesting they provided adequate thermal environments for the birds. However, litter temperatures were significantly higher in the afternoon as a result of the higher RHL values determined in this period.

Table 5 – Mean and standard error (values between parentheses) of radiant heat load (RHL), black globe humidity index (BGHI), and litter temperature (LT) according to litter substrate and period of the day.

	RHL (W m^{-2})	BGHI	LT (°C)		
			Surface	Internal	Bottom
Period					
Morning	451.64(52.75)a	70.22(3.67)a	22.39(3.04)a	21.02(2.37)a	19.81(1.63)a
Afternoon	480.27(42.11)b	74.01(3.95)b	25.62(3.46)b	23.17(2.61)b	21.03(1.86)b
Litter substrate					
Wood shavings	461.42(54.10)	72.03(4.31)	23.80 (3.51)	22.04(2.69)	20.43(1.86)
Rice husks	468.37(47.51)	72.17(4.30)	24.59(3.87)	22.44(2.80)	20.24(1.54)
Grass hay	461.36(51.38)	72.03(4.29)	24.15(3.72)	22.14(2.73)	20.25(1.74)
Sand	467.52(48.01)	72.14(4.34)	23.07(3.24)	21.86(2.73)	20.99(2.39)
Peanut hulls	471.27(48.26)	72.19(4.16)	24.39(3.74)	22.01(2.64)	20.19(1.51)

Means followed by different letters were different by the test of Duncan ($p<0.05$).

Bowers *et al.* (2003), comparing sand with pine shavings as litter substrates for broilers, reported that the litter surface temperature of sand was significantly lower than that of pine shavings both in the summer and fall, while Cordeiro *et al*. (2007) did not find any temperature differences between wood shavings and rice husks.

The cheaper substrates were rice husks (R$ 120.00) and sand (R$ 150.00). The most expensive was wood shavings (R$ 280.00), followed by peanut hulls (R$200.00), and grass hay (R$ 160.00). In addition of the technical and animal health aspects, the choice of litter substrate also depends on its price, local availability, and destination after flock harvesting. In Jaboticabal, peanut hulls are readily available, because this city is located in a sugarcane planting area, and peanut is used for crop rotation with sugarcane.

CONCLUSIONS

The results of the present study show that using rice husks, wood shavings, peanut hulls, grass hay, and sand as litter substrate for red-winged tinamou production are all technically viable and have similar effects, although peanut hulls and sand presented higher microbial counts and released higher ammonia levels, respectively.

Relative to litter quality, the use of grass hay, wood shavings, and rice husks as litter substrates is recommended as these presented lower microbial counts, higher water holding capacity, and lower released ammonia levels compared with peanut hulls and sand.

Therefore, litter substrate for red-winged tinamous should be chosen at farmer's discretion, and should take into account its price, availability, and destination after use.

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