Potential of pelleted wheat straw as an alternative bedding material for broilers

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ABSTRACT Broiler chickens are commonly placed on wood shavings as litter, but alternative litter sources are required due to the scarcity of wood shavings in many parts of the world. This study aimed to compare pelleted straw, chopped wheat straw, wood shavings, rice hulls, and shredded paper as litter candidates. Three-hundred-sixty Ross 308 one-day-old male chicks were used in this study. There were 5 litter treatments with 6 replicate pens, each with 12 birds. The feed conversion ratio (FCR) of birds reared on pelleted straw was improved compared ($P < 0.05$) to that of birds raised on rice hulls, whereas it did not differ for birds placed on wood shavings, rice hulls, chopped straw, or shredded paper. It was observed that the birds reared on wood shavings had higher relative gizzard weight at d 24 compared to those reared on pelleted straw ($P < 0.05$). Gizzard pH and measured cecal bacterial groups were not affected by the type of bedding material. Cecal bacterial groups measured at d 10 were not affected by bedding material. Birds reared on pelleted wheat straw had a lower incidence of footpad lesions than those on chopped straw and shredded paper on d 24 ($P < 0.001$) and 29 ($P < 0.01$). Litter source did not affect the occurrence of breast blisters at d 24, 29, or 35. On d 24, 29, and 35, pelleted straw litter was less caked than chopped straw and shredded paper ($P < 0.001$) whereas no significant differences were observed among pelleted straw, wood shavings, and rice hulls. The study demonstrated the potential benefits to using pelleted wheat straw as a bedding material. Further assessment of pelleting of wheat straw and other materials on broiler health, performance, and welfare are needed to determine the economic benefits of pelleted litter.

Key words: pelleted wheat straw, litter, performance, microflora, welfare

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INTRODUCTION

In the current rearing system broiler chickens are commonly placed on bedding materials or litter from one d old to market age. The aim of using litter is to absorb moisture from the excreta of birds thus keeping the environment reasonably dry and suitable for the broilers to grow without developing lesions. Litter provides birds with a proper medium on which watering, feeding, and other management practices are carried out (Monira et al., 2003).

Various types of bedding materials are used worldwide. Wood shavings remain the standard choice for poultry litter. As a consequence, the broiler industry uses a large quantity of processed solid wood residue. With the growing popularity of poultry meat, leading to rapid expansion of broiler production, wood shavings have become more scarce and costly (Garcês et al., 2013). Other litter materials, such as rice hulls, cane bagasse, sawdust, corn cobs, oat hulls, recycled paper, and wheat straw have been targeted for their high capacity to absorb moisture (Hafeez et al., 2009). Replacement of wood shavings by other litter sources depends on economics and availability. Shredded paper, wheat straw, and rice hulls have become attractive alternative sources as they can be obtained locally and cheaply. Generally, most research suggests that recycled paper litter could support performance and carcass quality of birds comparable to conventional bedding materials. Paper-based litter generally has high water-holding capacity (Malone and Gedamu, 1995). However, shredded or ground paper products can be dusty and susceptible to litter caking (Malone and Gedamu, 1995). Chopped wheat straw as alternative broiler litter also has its limitations as its large particle size may have a direct and negative effect on animal welfare, particularly footpads (Cengiz et al., 2011). Therefore, the physical and chemical characteristics of bedding materials have become important as it has been realized that broilers will not reach their genetic potential for weight gain and feed conversion when reared with suboptimal litter conditions (Huang et al., 2009; Torok et al., 2009; Sirri et al., 2010).

The efficiency of a specific bedding material relies on many characteristics such as the capacity to absorb

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water, to reduce moisture content, to alleviate caking, and to have an appropriate particle size (Brake et al., 1992). Wet litter can significantly reduce broiler welfare and productivity (de Jong et al., 2014). Birds grow fast during the first 3 wk of age and after that they spend a considerable amount of time sitting on the floor (Alvino et al., 2009). During the sitting time, the bird's chest and footpads are directly in contact with litter. Wet litter increases the incidence of footpad dermatitis (**FPD**), breast skin blisters, coccidiosis, fungal infections, and intestinal parasites (Greene et al., 1985; Martland, 1985; Monira et al., 2003; Allain et al., 2009). This reduces carcass quality and increases the risk of rejection at the processing plant. It is well known that birds consume litter during the early stages of grow-out (Malone et al., 1983) especially when they are fed low fiber diets (Hetland et al., 2005). The consumption of the bedding material may offer health benefits by increasing gizzard activity and gizzard size (Malone et al., 1983; Hetland et al., 2005). Torok et al. (2009) found that bedding materials impact broiler aecal microbial populations, at d 14 and d 28, particularly when reused litter as compared to new litter materials was used. Although the FCR was not different between groups, birds on used litter had lower live weight at 14 d of age ($P < 0.05$). Additionally, younger birds were found to exhibit greater variability in cecal microflora composition than older birds indicating the immature intestinal microflora population at an early age is easily influenced by litter type and may be responsible for some of the differences detected in early bird growth rate. Basically, Toghyani et al. (2010) presented similar observations except that no growth data were shown for younger birds. Although it appears that litter types may not have substantial impact on bird performance, their effect on bird welfare is not clearly understood. Processing is known to affect the physical and chemical attributes of fiber. It is unknown how steam pelleting of wheat straw may affect its water-holding capacity when used as a litter material. Furthermore, whether specially made bedding materials such as pelleted straw can be beneficial to birds in terms of their performance and welfare has not been assessed to the best of our knowledge. The present study was designed to investigate the influence of pelleted wheat straw as a bedding material on broiler performance, gut microflora, and welfare in contrast to other litter sources commonly used in the broiler industry.

MATERIALS AND METHODS

Design and Husbandry

All bird handling procedures were conducted according to the guideline for the care and use of farm and laboratory animals and approved by the Animal Ethics Committee at University of New England (Approval No: AEC14-012). Three-hundred-sixty one-day-old male Ross 308 chicks were obtained on the hatching day from Baiada Hatchery in Tamworth, NSW. All chicks were vaccinated against infectious bronchitis and Marek's disease in the hatchery. On arrival, broiler chicks were allocated to 30 pens measuring 75×120 cm with each pen stocked with 12 birds. A completely randomized design was used with 5 treatments replicated 6 times. The treatments were 5 different litter types applied from d one of the experiment: rice hulls, wood shavings, pelleted wheat straw, chopped wheat straw, and shredded paper. All bedding materials were spread evenly to a depth of approximately 7 cm in each pen. Each pen was equipped with 2 Lubing cup water drinkers and a tube feeder with water and feed available ad libitum. The lighting, relative humidity, and temperature followed Ross 308 guidelines.

Diets

All birds were fed the same diets in 3 phases: starter (placement to d 10), grower (d 10 to 24), and finisher (d 24 to 35). All diets were wheat, sorghum, canola meal, soybean, meal and meat meal based to meet Ross 308 nutrient specifications for digestible amino acids, minerals, and metabolizable energy. Table 1 shows the ingredient and nutrient composition of each diet.

Performance Measurement

Pen weights and feed consumption were measured for each period on d 10, 24, and 35 with mortality recorded daily. Feed conversion ratio (**FCR**) was corrected for weights of dead birds for each period. Feed intake was then calculated as weight gain (**WG**) x FCR for each period.

Litter Uality (structure) and Moisture Content

Litter quality (structure) was scored per pen by visual inspection at d 24, 29, and 35. Litter was scored using a 4-point scale (ranging from 0 to 3): 0 = dry; 1 = slightly moist/caked; 2 = more moist/caked; 3 = wet.

On d 35, litter samples of approximately 1.5 kg were collected in plastic bags from 4 locations within each pen. Individual litter samples were separated and weighed before and after drying in a forced air oven at 105°C for 24 h (Barker et al., 2013) to determine moisture content.

Gizzard Weight and pH, and Cecal Content Collection

On d 10, 24, and 35, 3, 2, and 2 birds, respectively, were randomly selected from each pen, weighed, and euthanized by cervical dislocation. Relative weight of empty gizzard and gizzard contents were determined using a digital scale. Gizzard contents from 2 birds

Table 1. Ingredient and nutrient composition of the basal diets (g/kg).

Item	Starter	Grower	Finisher
Ingredient			
Wheat	432.6	479. 2	515.9
[1]SBM	258.8	181.5	121.8
Sorghum	200.0	200.0	200.0
Canola meal solvent	30.00	50.0	80.0
Meat meal	30.00	35.99	24.76
Canola oil	20.43	32.37	38.42
Limestone	9.16	7.20	7.29
Dicalcium phosphate	4.20		
L-lysine HCl 78.4	3.72	3.27	2.66
DL-methionine	3.49	2.80	1.875
Na bicarbonate	2.00	2.00	2.00
L-threonine	1.993	1.646	1.154
NaCl	1.324	1.221	1.357
[2]UNE TM (0.75 kg/mt inclusion)	0.750	0.750	0.750
Choline Cl 70%	0.592	0.586	0.566
[3]UNE Vit (0.5 kg/mt inclusion Pre)	0.500	0.500	0.500
[4]Albac 150 (ZnBac) (0.33 kg/mt)	0.330	0.330	0.330
[5]Phyzyme XP5000G (100 g/mt) Dupont	0.100	0.100	0.100
Xylanase powder (50 g/mt)	0.050	0.050	0.050
Salino (120 g/kg)		0.500	0.500
Nutrient composition			
ME, kcal/kg	3,025	3,150	3,200
Crude protein	225.7	205.8	186.0
Crude fat	43.00	55.53	60.71
Crude fibre	25.87	26.06	27.14
Digestible arginine	13.10	11.40	9.90
Digestible lysine	12.70	11.00	9.40
Digestible methionine	6.40	5.52	4.44
Digestible Met + Cys	9.40	8.40	7.30
Digestible tryptophan	2.46	2.116	1.870
Digestible isoleucine	8.76	7.755	6.96
Digestible threonine	8.30	7.30	6.30
Digestible valine	9.88	8.871	8.03
Calcium	9.00	7.80	7.00
Phosphorus avail	4.50	3.90	3.50
Sodium	1.600	1.600	1.600
Chloride	2.26	2.13	2.02
Choline, mg/kg	1,600	1,500	1,400
Linoleic (18:2)	13.80	16.35	17.62

[1]Soybean meal.

[2]Trace mineral premix supplied per kilogram of diet: Cu (sulphate), 16 mg; Fe (sulphate), 40 mg; I (iodide), 1.25 mg; Se (selenate), 0.3 mg; Mn (sulphate and oxide), 120 mg; Zn (sulphate and oxide), 100 mg; cereal-based carrier, 128 mg; mineral oil, 3.75 mg.

[3]Vitamin concentrate supplied per kilogram of diet: retinol, 12000 IU; cholecalciferol, 5000 IU; tocopheryl acetate, 75 mg, menadione, 3 mg; thiamine, 3 mg; riboflavin, 8 mg; niacin, 55 mg; pantothenate, 13 mg; pyridoxine, 5 mg; folate, 2 mg; cyanocobalamin, 16 μg; biotin, 200 μg; cereal-based carrier, 149 mg; mineral oil, 2.5 mg.

[4]Zinc bacitracin (Albac 150) was purchased from Ridley AgriProducts, (Tamworth, NSW, and Australia).

[5]Phyzyme XP5000G: a phytase feed enzyme from Danisco Animal Nutrition.

were collected and homogenized for pH measurement (EcoScan pH 6). For the quantification of total bacteria, *Enterobacteriaceae*, and *lactobacilli*, approximately one g of cecal digesta was collected in a 2-mL Eppendorf tube, snap-frozen in liquid N_2, and stored at $-20°C$ until DNA extraction.

Quantification of Cecal Bacteria

Cecal DNA was extracted according to the ISOLATE II Plant DNA Kit (Bioline, NSW, Australia) protocol for fecal samples with slight modification. Approximately 200 mg of freshly defrosted cecal content and 300 mg of glass beads were placed in a 2-mL Eppendorf tube. Then 450 μl Lysis Buffer PA1 were added and mixed using a vortex mixer. The samples were transferred to Mixer Mill MM 300 (Retsch GmbH & Co, Haan, Germany), disrupted at a frequency of 30/s for 5 min, and heated at 95°C for 5 minutes. The digesta were lysed and homogenized after adding 200 μL of extraction buffer, followed by vortexing. An aliquot of 100 μL of extraction buffer was added and centrifuged at 4,600 $\times$ g for 10 minutes. Then 600 μL of the lysate were transferred into a 1.5-mL microcentrifuge tube, 10 μL RNase were added to remove RNA, and then the solution was incubated at 65°C. The incubated mixture was centrifuged for one min at 11,000 $\times$ g. An aliquot of 450 μL of Binding Buffer was used to capture DNA by vortexing thoroughly and then centrifuging for one min at 11,000 $\times$ g. Wash Buffer PAW1 (400 μL) and PAW2 (700 μL) were applied at independent steps to purify DNA, centrifuged for one min at 11,000 $\times$ g to remove the wash buffer and to dry the silica membrane completely. Then 50 μL of Elution Buffer was used to elute DNA into a 1.5-mL Eppendorf tube.

The methods reported by Wise and Siragusa (2006), Shannon et al. (2007), and Requena et al. (2002) were performed for the quantitative PCR of *Enterobacteriaceae*, total bacteria, *lactobacilli Bifidobacteria*, *Salmonella*, and *Clostridia*. The extracted cecal DNA was diluted 20 times in autoclaved Milli-Q water; a SensiMix™ SYBR® (Bioline, Sydney, Australia) Kit was used for the quantification of total bacteria, *Enterobacteriaceae*, *Lactobacilli*, *Bifidobacteria*, *Salmonella,* and *Clostridia*. The below specific 16 rRNA primers were used: CATTGACGTTACCCGCAGAAGAAGC and CTCTACGAGACTCAAGCTTGC for *Enterobacteriaceae*; CGATGAG TGCTAGGTGTTGGA, and CAAGATGTCAA GACCTGGTAAG for *Lactobacillus* spp.; CGGYCCAGACTCCTACGGG and TTACCGCGGCTGCT GGCAC for total bacteria; GCGTCCGCTGTGGGC and CTTCTCCGGCATGGTGTTG for *Bifidobacterium*; ATGCAAGTCGAGCGAKG, and TATGCGGTATTAATCTYCCTTT for *Clostridium*, and CGTTTCCTGCGGTACTGTTAATT and AGACGGCTGGTACTGATCGATAA for *Salmonella*.

The Rotorgene 6500 real-time PCR machine (Corbett, Sydney, Australia) was employed for quantification of the bacteria under investigation. The PCR were performed in duplicate for each sample in 10 μL of reaction. A threshold cycle (**CT**) average from the replicate cecal DNA samples was used for data analysis and repeat was conducted when the differences among the replicates were greater than 0.5 CT. Serial dilutions of linearized plasmid DNA (pCR®4-TOPO Vector, Life Technologies, Carlsbad, USA) inserted with respective bacterial amplicons were used to construct a standard curve. The NanoDrop ND-8000 (Thermo Fisher Scientific, Waltham, MA) was employed to measure the concentrations of the plasmid DNA. The copies of amplicons were calculated from the mass of plasmid DNA taking into account the size of the amplicon insert. The quantified bacteria were expressed as $\log_{10}$ (genomic DNA copy number)/g digesta.

Scoring System

Two birds from each pen were scored for FPD and breast blister (**BB**) on d 24, 29, and 35. The score of footpad dermatitis was determined according to the method of Allain et al. (2009). A 10-point (ranging from 0 to 9) scale was used based on extent and appearance of lesions: 0 indicated no lesions and 9 the most macroscopic deep lesions. The breast burn was scored using a 3-point (0 to 2) scale: 0 refers to no lesion and no discoloration, 1 refers no lesion but slight red discoloration, and 2 refers to breast burn or blistering and severe red discoloration (Cressman, 2014).

Statistical Analysis

The SAS statistics version 9.3 (SAS Institute, Cary, NC) was used to perform statistical analysis. The data were analyzed using one-way ANOVA with litter type as the factor. The significant difference between means was measured using the Tukey test, and the P-value at 0.05 level was used as a criterion of statistical significance.

RESULTS

Broiler Performance

Growth performance of broilers was affected by litter type at d 10 but not thereafter (Table 2). FCR of birds reared on pelleted wheat straw was improved compared to those reared on chopped straw ($P < 0.05$), whereas it did not differ in birds reared on wood shavings, rice hulls, or shredded paper. During the period one to 10, one to 24, and one to 35 d, no significant differences in weight gain and feed intake were observed among birds reared on different types of litter. However, on d 24, birds reared on wood shavings tended ($P = 0.054$) to have better FCR when compared to those reared on shredded paper or rice hulls.

Effect of Litter on Gizzard

The effect of litter type on the relative gizzard weight and gizzard content are shown in Table 3. Birds placed on wood shavings had higher ($P < 0.05$) gizzard relative weight at d 24 compared with those reared on pelleted straw. However, no effect of litter type on relative gizzard weight was detected at d 35. In addition, litter type had no impact on gizzard pH and gizzard content at d 10, 24, or 35.

Effect of Litter on Gut Microflora

Bacterial counts in the cecal contents were quantified at d 10 as shown in Table 4. No significant differences in measured cecal bacteria were observed across different litter types.

Incidence of Footpad Dermatitis and Breast Blister

The effects of litter materials on FPD and breast blister in broilers are presented in Table 5. Average FPD was affected by litter type. At d 24, birds reared on pelleted wheat straw and wood shavings had a lower incidence of footpad lesions compared to those reared on chopped straw or shredded paper ($P < 0.05$). At d 29, birds reared on pelleted wheat straw also showed lower

Table 2. Impact of litter type on growth performance on d 10, 24, and 35.

Item	Rice hulls	Wood shavings	Pelleted straw	Chopped straw	Shredded paper	P-value
Body weight gain, g/bird						
1 to 10 d	273	269	279	266	272	0.332
1 to 24 d	1,293	1,322	1,359	1,296	1,331	0.218
1 to 35 d	2,485	2,521	2,523	2,472	2,602	0.064
Feed intake, g/bird						
1 to 10 d	330	314	318	318	317	0.304
1 to 24 d	1,706	1,678	1,750	1,702	1,767	0.129
1 to 35 d	3,573	3,666	3,689	3,586	3,844	0.071
Feed conversion ratio						
1 to 10 d	1.209[a]	1.167[a,b]	1.137[b]	1.193[a,b]	1.164[a,b]	0.026
1 to 24 d	1.320	1.270	1.289	1.313	1.328	0.054
1 to 35 d	1.438	1.454	1.461	1.451	1.477	0.614
Livability, %						
1 to 10 d	100	99	99	99	100	0.735
1 to 24 d	99	99	96	99	97	0.768
1 to 35 d	99	94	96	97	96	0.640

[a,b]Means in rows with different superscripts are significantly different ($P < 0.05$).

Table 3. Impact of litter type on gizzard pH and relative weight of empty gizzard and gizzard content of broiler chickens at d 10, 24, and 35 of age.

Treatments	Day 10			Day 24			Day 35		
	Gizzard pH	Gizzard weight, %	Gizzard content, g	Gizzard weight, pH	Gizzard %	Gizzard content, g	Gizzard pH	Gizzard weight, %	Gizzard content, g
Rice hull	2.98	3.22	6.03	2.79	$2.067^{a,b}$	13.11	3.03	1.438	15.23
Wood shaving	2.97	3.28	6.12	2.83	2.155^{a}	13.27	2.91	1.436	14.26
Pelleted straw	3.03	3.00	6.84	2.80	1.787^{b}	13.62	2.99	1.298	11.56
Chopped straw	3.01	2.96	5.97	3.11	$1.993^{a,b}$	15.23	2.87	1.465	14.11
Shredded paper	2.88	3.00	5.89	3.11	$1.892^{a,b}$	15.42	3.07	1.281	10.66
P-value	0.842	0.091	0.401	0.149	0.009	0.786	0.833	0.555	0.444

[a,b]Means sharing the same superscripts are not significantly different from each other at $P < 0.05$.

Table 4. Bacterial quantification ($\log_{10}$ CFU) in cecal content of birds housed on different litter materials at d 10.

Treatments	Lactobacillus	Bifidobacteria	Salmonella	Enterobacteria	Clostridium	Total bacteria
Rice hulls	9.204	7.379	6.995	8.104	7.007	9.906
Wood shavings	8.828	7.203	6.986	8.215	6.849	9.712
Pelleted wheat straw	8.862	7.224	6.971	8.206	6.757	9.700
Chopped wheat straw	9.061	7.221	6.964	8.434	6.789	9.856
Shredded papers	8.904	7.262	7.039	8.388	6.754	9.622
P-value	0.354	0.612	0.863	0.486	0.272	0.110

Table 5. Impact of different types of litter on the incidence of footpad dermatitis and breast blister in broiler chickens at d 24, 29 and 35 of age.

Treatments	Day 24		Day 29		Day 35	
	[1]FPD	[2]BB	FPD	BB	FPD	BB
Rice hull	$1.167^{a,b}$	0.750	$1.583^{a\text{-}c}$	1.250	1.500	1.083
Wood shaving	0.583^{b}	0.583	$0.917^{b,c}$	0.833	1.250	0.500
Pelleted straw	0.250^{b}	0.333	0.750^{c}	0.833	1.083	0.583
Chopped straw	2.083^{a}	0.666	$2.083^{a,b}$	0.917	1.833	0.666
Shredded paper	2.333^{a}	0.917	2.500^{a}	0.583	2.333	0.917
P-value	0.001	0.123	0.002	0.172	0.081	0.200

[1]FPD: Footpad dermatitis.
[2]BB: Breast blister.
[a–c]Means sharing the same superscripts are not significantly different from each other at $P < 0.05$.

FPD than those raised on shredded paper or chopped straw ($P < 0.05$). However, there was no significant difference in the incidence of FPD in the birds reared on pelleted wheat straw and those reared on wood shavings or rice hulls on both d 24 and 29. No differences in FPD were detected among litter types on d 35. Litter type had no effect on the occurrence of breast blister at age 24, 29, or 35 days.

Litter Score and Moisture Content

The scores of the litter structure and litter moisture content are shown in Table 6. On d 24, 29, and 35, pelleted straw, rice hulls, and wood shavings litters were less caked than chopped straw or shredded paper ($P < 0.001$).

On d 35, the moisture content of the chopped straw was significantly higher than other litter types ($P < 0.001$) except shredded paper. There were no differences in moisture among shredded papers, wood shavings, pelleted straw, or rice hulls.

DISCUSSION

The main objective of the present study was to assess the performance and welfare of broiler chickens reared on pelleted wheat straw as opposed to commonly used bedding materials like rice hulls, wood shavings, chopped straw, and shredded paper. Several studies have suggested that litter type and mixed litter would affect bird performance and welfare (Huang et al., 2009; Youssef et al., 2010; El-Deek et al., 2011). However, other studies showed that litter type had no effect on performance and welfare (Monira et al., 2003; Hafeez et al., 2009). Our study showed that pelleted straw had an impact on performance at an early age of the birds along with some positive welfare implications. To the best of our knowledge, no report has been published to investigate the impact of pelleted straw on broiler performance, gut development, and welfare. Growth performance of broilers was affected by litter type at an early age. At d 10, the FCR of birds reared on pelleted straw was improved compared to those reared on rice hulls but no such improvement was apparent thereafter.

Table 6. Litter scores and moisture content at different days.

Treatments	Day 24 Litter score	Day 29 Litter score	Day 35 Litter score	Day 35 Moisture content, %
Rice hull	1.000[b]	1.000[b]	1.000[b]	28.565[b]
Wood shaving	1.167[b]	0.833[b]	1.000[b]	28.843[b]
Pelleted straw	0.667[b]	0.833[b]	1.000[b]	32.317[b]
Chopped straw	2.167[a]	2.000[a]	2.333[a]	43.095[a]
Shredded paper	2.000[a]	2.000[a]	2.167[a]	35.037[a,b]
P-value	<0.001	<0.001	<0.001	<0.001

[a,b]Means sharing the same superscripts are not significantly different from each other at $P < 0.0$.

This may be related to litter conditions and consumption as after 2 wk all litter sources became soiled with increased moisture. The wheat straw pellets lost durability and became loose between 10 and 14 d of age. On d 35, weight gain of birds tended to be highest in birds raised on shredded paper. This might be related to lower stocking density (18 kg/m^2) in the current study as compared to the industrial standard for Ross 308 (33 kg/m^2) (Ross-Broiler-Handbook, 2014). This is in agreement with the study of Malone and Gedamu (1995), who documented that birds placed on shredded or ground paper performed better than those reared on other litters when the stocking density was low. However, the reasons underlying this possible benefit of paper litter at low stocking density does not appear to be a result of litter consumption, gizzard weight, or relative differences among classes of bacteria residing in the ceca.

The results showed that relative gizzard weights, gizzard content pH, and gizzard content were unaffected by the type of bedding material in 10-day-old chicks. This indicates that birds did not consume sufficient amounts of litter to produce possible differences of these parameters. On d 24, the relative gizzard weights were heavier in the birds on wood shavings than pelleted straw and shredded papers, suggesting consumption of wood shavings during this time. Wood shavings retained its physical structure longer than shredded paper or pelleted straw, both of which were degraded into fine particle sizes. Hetland and Svihus (2001) found that the inclusion of coarsely ground oat hulls in the diet significantly increased the relative gizzard weight compared to that of birds fed a control diet and a diet with finely ground oat hulls, while no significant difference of gizzard content was found between birds fed coarsely and finely ground oat hulls. Wu et al. (2011) stated the increased amount of fiber in the diet and/or consuming of hardwood litter by broiler had the same impact as shown by feeding of coarse feedstuffs, i.e., enhanced development of the gizzard. However, the effect of litter on gizzard weight did not continue in the current study. Malone et al. (1983) reported that the consumption of bedding materials decreased after 3 weeks. Therefore, perhaps lower consumption of litter is the reason for the disappearance of the litter effect on gizzard weight.

In this study, the caking rate of the litter was observed to be higher with both chopped straw and shredded paper in comparison to other types. Materials with a large initial particle size (as in shredded paper and chopped straw) had a tendency to form cakey litter easily. Malone et al. (1982) concluded that the reduced particle size of processed newspaper may decrease litter caking. Thus a small particle size of paper litter may be needed to reduce the caking rate at a later stage of broiler grow-out. As expected, the litter cake scores showed similar trends with the percentage of moisture content in litter. The moisture content of chopped straw was significantly higher than pelleted wheat straw, wood shavings, and rice hulls. This could be related to the water-holding capacity and water-releasing capacity. Farhadi (2014) reported that the water-holding capacity of wheat straw was higher than wood shavings and rice hulls and the evaporation rate in wheat straw was lower.

The stocking density of birds, litter particle size, type of litter, and litter moisture and caking have been documented as main contributing factors to bird welfare (Dawkins et al., 2004; Haslam et al., 2007; Mayne et al., 2007; Bilgili et al., 2009). Of all bedding materials examined, pelleted straw showed the lowest incidence of footpad dermatitis. At d 24 and 29, the occurrence or appearance of footpad dermatitis was significantly lower in birds reared on pelleted straw compared to those placed on chopped straw and shredded paper. This could be related to water-absorbing capacity and evaporation rate as pelleted straw is more compact than chopped straw resulting in less cakey litter and fine particle size. Bilgili et al. (2009) stated the sharp edges of chopped straw may be responsible for the incidence of FPD. Cengiz et al. (2011) demonstrated that litter with a large particle size and high moisture level was related to the development of FPD. On d 35, the incidence of FPD in birds raised on chopped straw and shredded paper tended to be higher ($P = 0.081$) than in birds raised on other types of litter. Litter moisture and caking scores were high, which could be responsible for the higher incidence of FPD. The result at d 35 of this study shows that there is a strong correlation between moisture content and caking score ($P = 0.001$) and also between litter caking and FPD ($P = 0.009$) (Mayne et al., 2007; Bilgili et al., 2009) reported a strong correlation between high litter moisture and caking scores and the incidence of FPD.

In conclusion, this study demonstrated that litter type may contribute to welfare and performance difference, and that there are potential benefits with use of pelleted wheat straw as a litter material. However, the high pelleting costs for making the product could render it uneconomic to use in the broiler industry. Further assessment of pelleting of wheat straw and other materials on broiler health, performance, and welfare are needed to determine the economic benefits of pelleted litter.

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REFERENCES

Allain, V., L. Mirabito, C. Arnould, M. Colas, S. Le Bouquin, C. Lupo, and V. Michel. 2009. Skin lesions in broiler chickens measured at the slaughterhouse: Relationships between lesions and between their prevalence and rearing factors. Br. Poult. Sci. 50:407–417.

Alvino, G. M., G. S. Archer, and J. A. Mench. 2009. Behavioural time budgets of broiler chickens reared in varying light intensities. Appl. Anim. Behav. Sci. 118:54–61.

Barker, K., C. Coufal, J. Purswell, J. Davis, H. Parker, M. Kidd, C. McDaniel, and A. Kiess. 2013. In-house windrowing of a commercial broiler farm during early spring and its effect on litter composition1. The J. Appl. Poult. Res. 22:551–558.

Bilgili, S., J. Hess, J. Blake, K. Macklin, B. Saenmahayak, and J. Sibley. 2009. Influence of bedding material on footpad dermatitis in broiler chickens. J. Appl. Poult. Res. 18:583–589.

Brake, J., C. Boyle, T. Chamblee, C. Schultz, and E. Peebles. 1992. Evaluation of the chemical and physical properties of hardwood bark used as a broiler litter material. Poult. Sci. 71:467–472.

Cengiz, Ö., J. Hess, and S. Bilgili. 2011. Effect of bedding type and transient wetness on footpad dermatitis in broiler chickens. J. Appl. Poult. Res. 20:554–560.

Cressman, M. D. 2014. Effects of litter reuse on performance, welfare, and the microbiome of the litter and gastrointestinal tract of commercial broiler chickens. The Ohio State University.

Dawkins, M. S., C. A. Donnelly, and T. A. Jones. 2004. Chicken welfare is influenced more by housing conditions than by stocking density. Nat. 427:342–344.

de Jong, I. C., H. Gunnink, and J. van Harn. 2014. Wet litter not only induces footpad dermatitis but also reduces overall welfare, technical performance, and carcass yield in broiler chickens. J. Appl. Poult. Res. 23:51–58.

El-Deek, A., M. Al-Harthi, M. Khalifah, M. Elbanoby, and T. Alharby. 2011. Impact of newspaper as bedding material in arid land on broiler performance. Egypt. Poult. Sci. 31:715–725.

Farhadi, D. 2014. Short communication: Evaluation of the physical and chemical properties of some agricultural wastes as poultry litter material. Glob. J. Anim. Sci. Res. 2:270–276.

Garcês, A., S. Afonso, A. Chilundo, and C. Jairoce. 2013. Evaluation of different litter materials for broiler production in a hot and humid environment: 1. Litter characteristics and quality. J. Appl. Poult. Res. 22:168–176.

Greene, J. A., R. McCracken, and R. Evans. 1985. A contact dermatitis of broilers-clinical and pathological findings. Avian Path. 14:23–38.

Hafeez, A., S. Suhail, F. Durrani, D. Jan, I. Ahmad, and A. Rehman. 2009. Effect of different types of locally available litter materials on the performance of broiler chicks. Sarhad J. of Agric. 25:581–586.

Haslam, S., T. G. Knowles, S. N. Brown, L. Wilkins, S. C. Kestin, P. D. Warriss, and C. J. Nicol. 2007. Factors affecting the prevalence of foot pad dermatitis, hock burn and breast burn in broiler chicken. Br. Poult. Sci. 48:264–275.

Hetland, H., and B. Svihus. 2001. Effect of oat hulls on performance, gut capacity and feed passage time in broiler chickens. Br. Poult. Sci. 42:354–361.

Hetland, H., B. Svihus, and M. Choct. 2005. Role of insoluble fiber on gizzard activity in layers. J. Appl. Poult. Res. 14:38–46.

Huang, Y., J. Yoo, H. Kim, Y. Wang, Y. Chen, J. Cho, and I. Kim. 2009. Effect of bedding types and different nutrient densities on growth performance, visceral organ weight, and blood characteristics in broiler chickens. J. Appl. Poult. Res. 18:1–7.

Malone, G., P. Allen, G. Chaloupka, and W. Ritter. 1982. Recycled paper products as broiler litter. Poult. Sci. 61:2161–2165.

Malone, G., G. Chaloupka, and W. Saylor. 1983. Influence of litter type and size on broiler performance. 1. Factors affecting litter consumption. Poult. Sci. 62:1741–1746.

Malone, G., and N. Gedamu. 1995. Pelleted newspaper as a broiler litter material. J. Appl. Poult. Res. 4:49–54.

Martland, M. 1985. Ulcerative dermatitis dm broiler chickens: The effects of wet litter. Avian Path. 14:353–364.

Mayne, R., R. Else, and P. Hocking. 2007. High litter moisture alone is sufficient to cause footpad dermatitis in growing turkeys. Br. Poult. Sci. 48:538–545.

Monira, K., M. Islam, M. Alam, and M. Wahid. 2003. Effect of litter materials on broiler performance and evaluation of manureal value of used litter in late autumn. Asian Australas. J. Anim. Sci. 16:555–557.

Requena, T., J. Burton, T. Matsuki, K. Munro, M. A. Simon, R. Tanaka, K. Watanabe, and G. W. Tannock. 2002. Identification, detection, and enumeration of human Bifidobacterium species by PCR targeting the transaldolase gene. Appl. Environ. Microbiol. 68:2420–2427.

Ross-Broiler-Handbook. 2014. Housing and Environment. 96.

Shannon, K., D.-Y. Lee, J. Trevors, and L. Beaudette. 2007. Application of real-time quantitative PCR for the detection of selected bacterial pathogens during municipal wastewater treatment. Sci. Total Environ. 382:121–129.

Sirri, F., G. Minelli, E. Folegatti, S. Lolli, and A. Meluzzi. 2010. Foot dermatitis and productive traits in broiler chickens kept with different stocking densities, litter types and light regimen. Ital. J. Anim. Sci. 6:734–736.

Toghyani, M., A. Gheisari, M. Modaresi, S. A. Tabeidian, and M. Toghyani. 2010. Effect of different litter material on performance and behavior of broiler chickens. Appl. Anim. Behav. Sci. 122:48–52.

Torok, V. A., R. J. Hughes, K. Ophel-Keller, M. Ali, and R. Macalpine. 2009. Influence of different litter materials on cecal microbiota colonization in broiler chickens. Poult. Sci. 88:2474–2481.

Wise, M. G., and G. R. Siragusa. 2006. Quantitative analysis of the intestinal bacterial community in one to three week old commercially reared broiler chickens fed conventional or antibiotic free vegetable based diets. J. Appl. Microbiol. 102:1138–1149.

Youssef, I., A. Beineke, K. Rohn, and J. Kamphues. 2010. Experimental study on effects of litter material and its quality on foot pad dermatitis in growing turkeys. Int. J. Poult. Sci. 9:1125–1135.