Use of industrially produced litter material from waste paper sludge as litter in broiler houses

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SUMMARY

The aim of the current study was to evaluate the "Gaia" as a bedding material and find out the possible effects on the broiler performance, foot pad dermatitis (FPD), breast feather loss (BFL) and litter characteristics. The study was conducted with 3492 mixed-sex Ross 308 chicks reared under standard commercial-broiler growing conditions in two environmentally similar closed poultry houses and using either pine shavings (PS, 4.5 kg/m^2) or paper waste (PW, 3.5 kg/m^2) as litter. Three replicates were used for each litter type. The results showed litter material had no effect on poultry performance in terms of live weight, feed efficiency, or viability; however, in comparison to the PS group, the PW group had significantly higher mean foot pad dermatitis (FPD) scores (0.07 vs 0.10; P<0.05) and lower breast feather loss (BFL) scores (1.83 vs. 62; P<0.05). There is no significant difference among treatments in terms of litter pH, ammonia concentrations, and moisture levels. Moreover, due to the high drying temperature of the PW, it has no microbial load. As a result, it was concluded that because PW has no adverse effect on poultry performance characteristics, the material can be used as poultry litter.

KEY WORDS

Breast feather score, Broiler performance, Foot pad dermatitis, Litter, Moisture, pH.

INTRODUCTION

Litter is used in broiler production to prevent chicks from coming into direct contact with the ground. Choice of litter material is based upon numerous factors, including availability, usability, price, insulating capacity, water holding capacity, animal comfort, lack of harmful effects to animals, humans and the environment, and opportunities for subsequent use as fertilizer or fuel[1,2].

Litter is an important material in ensuring that animal health and welfare, food safety and environmental requirements are maintained at an optimum level and that production performance and efficiency is maintained[2,3,4].

According to Toghyani et al.[5], the humidity, pH, ammonia, dust and microbiological properties of litter are as important as in-house conditions in poultry production. Litter material has an effect on broiler physiological and behavioral characteristics[1], growth characteristics, and animal welfare and immune systems[6].

Specifically, negative litter characteristics not only may lead to the development of breast, foot joint (hock), foot-pad and finger lesions but also adversely affect carcass characteristics, which may results in economic losses[1]. It is more likely that during the production, litter materials are mixed with manure, feathers, feed and water containing a variety of microorganisms, salts, nutrients and other wastes[7]. Ammonia level[8,9] and digestive tract microbiota[10,11] have a crucial effect on growth and other characteristics of broilers.

In many countries, wood shavings, which have a particle size of about 1-3 cm and are obtained from the lumber and furniture industries, are preferred as litter material for intensive broiler production[4]. Recently the demand of wood shavings has increased not only in broiler production capacity but also increase in the use of fuel and hardboard production. Increase in the price of wood shavings has resulted in the increased cost of broiler production[13,14,15].

Therefore considerable attempts has been diverted in finding alternative litter material such as paper wastes[16], gypsum[17], hardwood bark[18], kenaf[19], hazelnut husks[20], rice and wheat straw[21], rice hulls[22], rice hull ash[23] and sawdust[24], sand, zeolite, vermiculite, and sepiolite[8,27,29], tree leaves[30,31,32], composted municipal garbage[33] and cellulose-based industrial wastewater byproducts[14]. A number of studies have also examined the possibilities of reuse litter[13,34,35].

Recently waste sludge has been converted into a commercial product called "Gaia" in Turkey (IKMAK Plastic Industry Trade Limited, 2016, Duzce, Turkey) for bedding material. The commercial product is the waste sludge produced during the recycling of paper and cardboard production and may be an alternative to the commonly used wood shavings. Ritz et al.[14] also suggested that cellulose-based material mixed with feces at the end of broiler production can be utilized as a fertilizer for plant production.

Although the sludge has been used alone or in combination with rice hulls as bedding materials in broiler house[36,50], so far, this commercial product called "Gaia" has not been tested as a bedding material in broiler production. Therefore the aim of the current project was to evaluate the Gaia as a bedding material and find out the possible effects on the broiler performance, foot pad dermatitis (FPD), breast feather loss (BFL) and litter characteristics.

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Table 1 - Material characteristics of the PW litter used in the study.

Analysis paremeters	Unit	Analysis results*	Max. criteria
pH (24°C)	-	5.6	-
Organic matter	%	77.6	-
Humidity (70°C)	%	13.8	-
Organic Carbon (C)	%	55.5	-
C/N	%	16.8	-
Total humic+fulvic acid	%	36.04	-
Total Nitrogen (N)	%	3.3	-
Total P_2O_5	%	1.4	-
Soluble in water K_2O	%	2.6	-
Heavy metals accepted upper limits			
Cadmium (Cd)	mg/kg	0.83	3
Copper (Cu)	mg/kg	76.97	450
Nickel (Ni)	mg/kg	8.34	120
Lead (Pb)	mg/kg	2.47	150
Zinc (Zn)	mg/kg	315.3	1100
Mercury (Hg)	mg/kg	<0.01	5
Chromium (Cr)	mg/kg	4.37	350
Tin (Sn)	mg/kg	<0.01	10

***** Analysis was performed at the LABEN Agricultural Analysis Laboratory, a Turkish-accredited institution in Antalya, Turkey on April 20, 2016.

Figure 1 - Pine shavings (PS) and material obtained from waste-paper processing sludge (PW).

MATERIAL AND METHODS

The study was conducted at the Animal Production and Research Center of the Sutcu Imam University Faculty of Agricultural in Kahramanmaras, Turkey. The study complied with ethical guidelines and was conducted with the approval of the Local Ethics Committee for Animal Experiments (Project No. 2016/06).

Litter materials

The material used in this experiment is a cellulose slurry comprised of cellulose fibers and sediment sludge that is produced as a byproduct of recycled paper and cardboard processing and has an average moisture level of 75-80%. Prior to packaging, the material is dried at 120°C in a rotary-drum oven for 35-40 minutes, cooled, and passed through a 5-mm sieve. PW material characteristics are listed in Table 1.

Dust- and resin-free pine shavings (PS) were used as litter in the control group. Figure 1 shows examples of both the PW and PS litter. Litter was spread on the floor of poultry houses (PW: 3.5 kg/m²; PS: 4.5 kg/m²). Water-holding capacity was calculated according to Tüzüner[37] using the formula WHC = (wet net weight - dried net weight) / dried net weight x 100. WHC values for the litter materials used were found to be 268.3% (PS) and 140.6% (PW).

Production environment, animal material and rearing conditions

The study was carried out in two environmentally controlled poultry houses constructed at the research center during the same time period.

Each house is 7 m x 19 m, with 3-m high walls and an interior divided into 3 equal 44.27 m^2 sections (2.33 m x 19 m), with 60-cm wire fences.

The experiment was conducted with 3.492 mixed-sex Ross-308 broiler chicks.

Chicks were randomly divided into 2 groups (PW: Experimental group; PS: Control group) of three replications each.

Table 2 - Nutritional values of the feeds used in the trial.

Nutrient contents	Starter 1-10. days	Grower 1 11-20. days	Grower 2 21-33. days	Finisher 34-42. days
Dry matter (%)	88.0	88.0	88.0	88.0
Crude protein (%)	23.0	22.0	22.0	22.0
Crude cellulose (%)	6.0	6.0	6.0	6.0
Crude ash (%)	8.0	8.0	8.0	8.0
Metabolic Energy Kcal/kg	2805	2850	2850	3050
Metabolic Energy MJ/kg	11.744	11.932	11.932	12.770
Ca (%)	1.0-1.5	1.0-1.5	0.9-1.5	0.8-1.2
P (%)	0.70	0.70	0.65	0.60
Na (%)	0.15-0.30	0.15-0.30	0.15-0.30	0.15-0.30
NaCl (%)	0.35	0.35	0.35	0.35
Lysine (%)	1.30	1.20	1.10	0.90
Methionine (%)	0.60	0.50	0.50	0.35
Cystine (%)	0.32	0.40	0.30	0.30

Table 3 - Temperature and humidity values (at animal level) applied in the house during the experiment.

Age (Week)	Temperature (^{0}C)		Relative Humidity (%)	
	PS, Min, Max	PW, Min, Max	PS, Min, Max	PW, Min, Max
1	32.0 (30.0-33.0)	32.0 (30.0-33.0)	60.0 (55.0-65.0)	60.0 (56.0-65.0)
2	28.0 (27.0-29.0)	28.0 (27.0-29.1)	60.0 (57.0-67.0)	60.0 (58.0-67.0)
3	27.1 (24.1-31.1)	27.4 (24.9-31.4)	60.8 (36.5-70.7)	59.2 (63.4-65.9)
4	26.3 (24.0-29.7)	26.9 (23.6-30.7)	55.7 (28.3-70.8)	56.9 (31.3-71.0)
5	25.1 (21.7-27.0)	25.1 (21.6-27.0)	53.9 (31.1-69.6)	55.7 (32.6-68.5)
6	24.0 (18.6-26.9)	24.3 (19.1-26.2)	52.0 (39.5-75.9)	62.0 (38.1-76.3)

Chicks in the PW group were raised in 1 house, and chicks in the PS group were raised in the other house. A total of 582 chicks placed in each compartment (13.1 chick/m^2). Chicks were fed with commercial broiler rations obtained from a commercial feed factory. Nutrient contents of the feed used during the experiment are given in Table 2.

Feed was provided from spiral feeders (22 feeders per pen), and water was provided by watering lines with nipple drinkers (68 per pen).

Both feed and water were given ad-libitum throughout the experiment. Chicks were vaccinated against Newcastle, Gumboro and Infectious Bronchitis via drinking water during the growing period.

A light/dark regime of 23/1 hours was applied during the experiment. Illumination was provided by white bulbs. A light intensity of 18 lux was maintained at the level of feeders and monitored by a light monitor (Lutron LX-101). Houses were heated by thermostat-controlled infra-red electric heaters, with 3 heaters per house. Temperature and humidity values of both houses were kept similar during the trial period. In-house temperature and humidity values were automatically recorded every 15 minutes by HOBO U12 External Data Loggers and used to calculate daily and weekly average temperature and humidity. The average, maximum and minimum values are given in Table 3.

Litter traits

The ammonia concentration of the air just above the litter were measured at 35 and 42 days using ammonia analyzer (Drager Safety, Inc., 101 Technology Dr., Pittsburg, PA) placed at litter level in 3 separate zones in each compartment of the house, and mean, maximum, and minimum values were calculated. pH and moisture content of litter were measured at the end of the experiment in triplicate.

Broiler performance traits

Mortality was recorded daily, and weekly mortality rates were calculated cumulatively for each replication. Animals were weighed together at 7, 14, 28 and 35 days of age to determine total live weights per replication and weighed individually at 21 and 42 days of age to determine individual live weights. Feed consumption and feed efficiency were calculated for each replication at days 7, 14, 21, 28, 35 and 42. All animals were slaughtered at day 42.

Foot pad dermatitis (FPD) was evaluated at the end of the trial (42 days) from the left foot of each chicken. FPD scores were recorded as follows: 0: No lesions; 1: small point lesions, 2: lesions covering more than 25% of the foot; 3: lesions covering more than 50% of the foot; 4: lesions covering the entire sole of the foot ([12,38,49], Figure 2). Feather loss was evaluated on day 42 from the breast of each chicken and scored as follows: 0: no feather loss; 1: up to 25% feather loss; 2: up to 50% feather loss; 3: up to 75% feather loss; 4: complete loss of feathers (Figure 3[12,21]).

Statistical analysis

Statistical analysis was performed using the statistical software package SPSS (Version 21). Body weights, feed efficiency, mortality, and litter ammonia and fertilizer levels of the groups were compared using t tests, and FPD scores and BFL scores were compared using Mann-Whitney U tests. Statistical significance was set at a level of 0.05.

Score 0 Score 1 Score 2 Score 3 Score 4

Figure 2 - Foot pad dermatitis scoring.

Score 1 Score 2 Score 3 Score 4

Figure 3 - Feather loss scoring.

RESULTS AND DISCUSSION

Broiler performance traits

No health problems were observed during the experiment, and no additional medication was used. Live weights and feed efficiency (7 to 42 days of age) and mortality rates (0 to 42 days of age) for both litter groups are presented in Table 4, and changes in live weights, feed efficiency and mortality rates are shown in Figures 4, 5, and 6, respectively. Broiler chickens in both groups reached live weights of more than 2 kg in 35 days. Statistical analysis showed live weights, feed efficiency and mortality rates were not significantly affected by litter material. Feed efficiency at 42 days of age were also similar for both groups as were mortality rates.

While the majority of studies examining commonly used litter materials as well as litter materials particular to certain regions have reported no differences in broiler live weights, feed consumption, feed efficiency, or viability in connection with litter type[14,23,29,40], some studies have reported litter materials to have significant effects on various performance traits[4,20,27]. The PW litter material used in this study is similar to the litter material used by Ritz et al.[14] and Villagra et al.[50] they stated that the material can be used without affecting broiler performance.

Table 4 - Mean body weight (g), feed efficiency (g:g), and mortality (%) of Ross-308 broilers commercially reared with 2 different litter systems (PS vs PW).

Treatment	Mortality (%) $\bar{X}\pm S_x$	Body weight (g) $\bar{X}\pm S_x$			Feed efficiency (g/g) $\bar{X}\pm S_x$		
	d42	d7	d21	d42	d7	d21	d42
PS	1.89±0.062	165.9±0.15	931.2±6.78	2820.6±10.11	0.94±0.01	1.21±0.01	1.59±0.01
PW	2.34±0.057	165.3±1.08	922.7±2.93	2829.3±14.71	0.94±0.02	1.23±0.01	1.59±0.01
Mean	2.12	165.6	926.9	2824.9	0.94	1.23	1.59
p-value	0.164	0.612	0.316	0.823	0.864	0.162	0.793
Significance	NS	NS	NS	NS	NS	NS	NS

NS: Non significant differences.

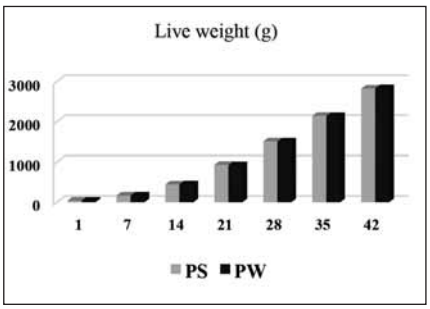

Figure 4 - Broiler live weights (g) by litter system (PS and PW) and age (1-42 days).

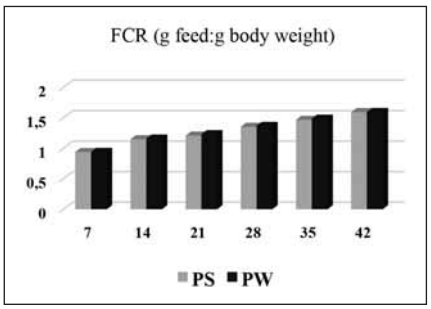

Figure 5 - Broiler feed conversion rates (kg feed: kg CA) by litter system (PS and PW) and age (7-42 days).

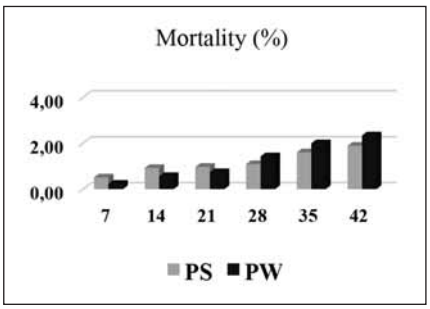

Figure 6 - Broiler mortality (%) by litter system (PS and PW) and age (7-42 days).

Broiler welfare traits

While the present study found no differences in broiler performance characteristics, FPD levels and BFL scores at 42 days of age were significantly affected by litter material ($P < 0.05$; Table 5), with mean FPD scores significantly higher ($P < 0.05$) in the PS group (0.07) as compared to the PW group (0.10). However, FPD scores of both litter groups were acceptable, with 96.40% of the PS group and 91.20% of the PW group scoring '0'.

Previous studies have noted that foot and breast defects as well as some welfare parameters may be affected by litter material[2,4,45,46]. For example, Yildiz et al.[28] reported statistically significant differences ($p < 0.05$) in FPD scores for sawdust (1.98), sawdust+vermiculite (1.02), and vermiculite (1.06) litter, and Bintas at al.[29] similarly found that adding either soil or zeolite to sawdust litter lowered FPD levels. Tercic et al.[12] also reported significant differences in FPD scores for wood shavings (1.00), shredded paper (1.15), and chopped wheat-straw pad litter (1.48). In contrast to these findings, Ritz et al.[14] found that while adding a cellulose waste-water by-product to pine-shaving litter significantly improved FPD scores during the early stages of broiler growth, the improvement was no longer significant at the end of the growth period, and Bilgili et al.[26] reported similar rates of FPD for sand and pine-shaving litters, with rates ranging between 10.1% and 28.0% over 3 different trials. Zikic et al.[46] found litter type and litter treatment with enzymatic-bacterial production incidence to have a significant effect on the severity of FPD in broilers, with scores ranging between 1.94 (Un-chopped) and 1.47 (Chopped). El-Wahab et al.[40] found the addition of Biotin and ZnO to feed of broilers raised on wood shavings resulted in significant differences in FPD scores, with scores ranging between 0.6-1.4 on a 7-point scale. Yamak et al.[35] reported that reuse of sawdust litter resulted in significant increases ($P < 0.05$) in FPD scores from 2.39 for fresh litter to 2.64 for reused litter, with the authors attributing these increases to increases in litter moisture and ammonia levels. El-Wahab et al.[40] also reported a significant relationship has between FPD levels and litter moisture and pH, with a 30% moisture level reported to be the critical cut-off point. Lien et al.[16] determined the breast-blisters scores in pine shavings and recycled paper chip litters as 13.2% and 10.7%, and foot abnormalities as 8.2% and 6.9% whereas FPD scores in the present study were significantly higher for the PW group, feather loss scores were significantly higher in the PS group (PS: 1.62; PW:1.83; $p < 0.05$). Tercic et al.[12] reported BFL to vary significantly ($P < 0.05$) according to litter type, with scores of 1.62, 1.81 and 2.71, respectively, for wood shavings, shredded paper and chopped wheat straw litter. Yildiz et al.[28] also found significant differences in breast feather scores between wood shavings (2.92), vermiculite (2.93), and wood shavings+vermiculite (2.89). Lima et al.[41] found that adding soil, sand and similar materials to litter as well as increasing litter height reduced breast feather loss. In terms of breast blisters, different studies have reported different results for different litter material. Although Willis et al.[30] reported similar scores of 1.4, 1.3, and 1.4, respectively, for wood shavings, 50% wood shavings + leaves, and leaves used as a litter, Bilgili et al.[26] reported breast-blister scores for different litters to range between 0-1.7, with scores lower for sand as compared to pine shavings, and Sarica and Cam[20] reported scores for various plant-product litter to range between 1.3 - 2.6, with the highest breast-blister scores occurring with wheat stalk litter.

Litter traits

Litter traits (ammonia, pH, moisture levels) did not vary significantly between the PS and PW groups (Table 6).

Ammonia concentrations measured at the litter surface on days 35 and 42 were similar and acceptable for both groups (day 35: PS, 10.1 ppm; PW, 11.8 ppm, day 42: PS: 11.8 ppm; PW: 13.3 ppm). Sarica and Demir[25] reported ammonia at litter levels to be 23.40 ppm for sawdust and 16.50 ppm for sawdust + zeolite. Chablee and Yeatman[23] evaluated ammonia concentrations in 3 different litter treatments (pine shavings, rice hull ash, 50% pine shavings + 50% rice hull ash) and reported levels of 22, 24 and 21 ppm, respectively. Bintas et al.[29] reported differences in sawdust litter particle size had no significant effect on ammonia levels, which ranged between 31.6 ppm-35.2 ppm. Miles

Table 5 - FPD and BFL scores of broilers at 42 days of age.

Treatment	FPD Scores						BFL Scores					
	$\bar{X}\pm S_{\bar{x}}$	0%	1%	2%	3%	4%	$\bar{X}\pm S_{\bar{x}}$	0%	1%	2%	3%	4%
PS	0.07 ± 0.01^{b} (0:0-4)	96.40	3.00	0.23	0.23	0.06	1.83 ± 0.03^{a} (2:1-4)	0	49.10	28.10	14.10	8.70
PW	0.10 ± 0.01^{a} (0:0-4)	91.20	8.10	0.23	0.41	0.12	1.62 ± 0.02^{b} (1:1-4)	0	60.40	22.90	11.50	5.20

[a, b]: scores indicated by different letters are different according to Mann-Whitney U test ($P < 0.05$).

Table 6 - Mean moisture, pH and ammonia concentrations (%) of litter materials.

Treatments	Moisture content (%)			pH		Ammonia concentration (ppm)	
	Initial	35 d	42 d	35 d	42 d	35 d	42 d
PS	12.2	25.3	24.2	7.12	7.62	10.1 (8^{1}-14^{2})	11.8 (10^{1}-16^{2})
PW	12.8	26.4	25.6	7.43	7.79	11.8 (7^{1}-16^{2})	13.3 (12^{1}-17^{2})
Mean	12.5	25.9	24.9	7.28	7.71	10.95	12.55
p-value	0.089	0.078	0.092	0.350	0.430	0.091	0.098
Significance	NS	NS	NS	NS	NS	NS	NS

[1]: Min, [2]: Max.

et al.[48] found ammonia levels measured at house walls, drinkers, and feeders to be 5.68 ppm, 12.3 ppm and 4.52 ppm, respectively. Ritz et al.[14] found ammonia levels to vary according to litter material, with levels ranging from 42.4 ppm to 75.4 ppm. These levels are high when compared to other studies. Apart from substrate, ventilation, litter moisture and settlement frequency also have a significant effect on litter ammonia levels[34]. In the present study, pH levels for the PS and PW litter groups were 7.12 and 7.62, respectively, on day 35 and 7.43 and 7.79, respectively, on day 42. The differences between litter groups were not statistically significant. The pH levels found in our study are similar to those reported by Onbasilar et al.[47] for wood shavings (7.5) and rice hulls (7.4). A study by El-Deek et al.[44] determined pH levels as 6.67 to 7.24 on different litter, and in the second research, they determined between 6.51 and 6.93. Studies by El-Wahab et al.[40] determined as higher pH value compared to reported research results (Experiment 1 between 8.48 and 8.61; Experiment 2 between 8.11 and 8.18). Similar high pH value (8.24 - 8.26) is determined by Lima et al.[41] and the findings from both studies are higher than the pH results from this study.

Moisture content of litter is the most important factor affecting ammonia levels, litter pH, and house humidity. The present study found initial moisture levels to be slightly higher for the PS group (PS: 12.2%; PW: 12.8%), whereas values were slightly higher for the PW group on day 35 (PS: 25.3%; PW: 26.4%) and day 42 (24.2% and 25.6%); however, the differences between groups were not statistically significant (Table 6). In general, when compared to the present study, previous studies reported higher litter moisture levels[18,20,29,39]. A number of studies have noted that when the moisture content in poultry house litter drops to 30% or below, both ammonia levels and FPD levels decrease as well[12,14,34,40].

As a result, based on the results obtained for broiler performance characteristics, FPD and BFL scores, and litter characteristics, commercial product called "Gaia" could be used as litter material in broiler production without compromising the broiler performance. However further investigation is required to test the feasibility of this commercial product in poultry production.

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