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Effect of different litter materials on growth performance, the gait score and footpad dermatitis, carcass parameters, meat quality, and microbial load of litter in broiler chickens

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ABSTRACT In the current study, the microbial load of litter materials, growth performance, the gait score and footpad dermatitis, carcass characteristics, and meat quality of broilers reared on different litter materials were investigated. After hatching and sex determination, the chicks were allocated to 3 different experimental groups with each having 8 replications. The chicks were reared on thick sawdust, fine sawdust, or rice hull litter materials. A total of 480 chicks were used with each replicate having 20 chicks (10 males, 10 females) of similar body weight. At the end of the experiment, a total of 96 chickens were slaughtered, 32 from each group with equal number of males and females. The effect of the experimental groups on body weight, mortality, and carcass characteristics were not significant; however, feed consumption and feed conversion ratio were significantly ($P < 0.05$) affected by the treatments in all weeks except the first 2 wk of the experiment. Different litter materials significantly ($P < 0.05$) influenced the foot health of the chickens as well as the microbial load of the litter. There was no significant difference between the treatment groups in terms of pH, color, and cutting resistance of raw meat however, the water loss during the cooking of the meat and the TPA analysis results such as hardness, springiness, and chewiness of the cooked meats were significantly ($P < 0.05$) affected by the type of litter material. It was concluded that the use of fine sawdust from trees such as pine and larch containing antimicrobial extracts would be more appropriate as a litter material in broiler production.

Key words: broiler, footpad dermatitis, litter material, meat quality, microbial load

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INTRODUCTION

Chicken meat is of great nutritional importance in the diet of human beings due to its nutrient density and composition. In addition, chicken production is easier and cheaper compared to the production of other livestock species. Therefore, chicken meat is one of the most consumed meats in the world. With the developments in animal breeding and the feed industry in recent years, the slaughter weight of broiler chickens has increased irrespective of short rearing or growing period. However, the performance of these chickens is not only affected by breeding and feeding but also the management conditions of the poultry unit. In particular, environmental conditions and the quality of litter materials are some of the factors that affect the growth rate and carcass quality of broiler chickens (Şekeroğlu et al., 2013). In broiler production, materials such as wood shavings, hazelnut husk, ground corn cobs, pieces of paper, rice hull, volcanic ash, and perlite are used as a litter material, but the most preferred is thick wood chips (Sarıca and Çam, 1998). Thick wood shavings are inconsumable by chicks due to their size, they are also a good insulator due to their porous and rough structure making them a good absorbent of water. However, in Türkiye, the use of thick wood chips as fuel in the winter months and its excessive demand in regions with intensive broiler production has increased the cost of this type of litter material in recent years (Özlü et al., 2017). For this reason, research on different or alternative sources of litter material for chicken production increased over the years, it was stated that the use of smaller and thinner fine sawdust reduces foot problems, but the hard and thick particle size of the thick sawdust increases the foot

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problems in chicks (Patricia et al., 1997). Furthermore, rice hull can be considered as a cheap alternative source of litter material in regions where rice production is intense and it is effective in preventing carcass defects (Bilgiç, 2008).

In the current study, the microbial load of litter materials, growth performance, the gait score and footpad dermatitis, carcass parameters, and meat quality of broiler chickens reared on different litter materials were investigated.

MATERIALS AND METHODS

Ethical Status

This study was approved by the Ethic Committee of Çukurova University (Approval no: 2022/3).

Animal Material, Feed Material, and Experimental Design

Ross 308-day-old broiler chicks were used in this study. After hatching and sex determination, the chicks were allocated to 3 different experimental groups with each having 8 replications, using thick sawdust, fine sawdust, and rice hull as litter materials. A total of 480 chicks were used with each replicate having 20 chicks (10 males, 10 females) of similar body weight. During the experiment, the animals were provided with feed and water ad libitum. Composition of raw materials and the nutrient contents of the feeds used in the experiment are presented in Tables 1 and 2.

Experimental Units and Environmental Conditions

The animals were reared in an environmentally controlled house with a total of 24 pens (1.5 × 2 m) and applied the light:dark cycle as 23L:1D. The stocking density in each pen was adjusted to 15 chicks/m^2. During the experiment, the environmental temperature and humidity were maintained within the comfort zone of the animals using a curtain and a tunnel ventilation system according to the recommendations of Ross (2018).

Table 1. The composition of raw materials in feeds used in the experiment (%).

Raw materials %	Starter feed (1−10 d)	Grower feed (11−24 d)	Finisher feed (25−35 d)
Corn 6.2% CP	49.01	49.97	51.56
Soybean meal 47% CP	37.81	32.24	27.07
Barley 12% CP	4.00	7.00	9.00
Soybean oil	3.17	4.23	5.28
Sunflower meal 33% CP	3.00	4.00	5.00
Limestone	0.75	0.65	0.55
Salt	0.27	0.27	0.26
Mineral premix*	0.20	0.20	0.20
DL-Methionine	0.36	0.32	0.28
L-Lysine HCl	0.17	0.16	0.15
Dicalcium phospahte	0.73	0.44	0.15
Sodium bicarbonate	0.11	0.12	0.13
Phytase	0.12	0.12	0.12
L-Threonine	0.15	0.13	0.10
Vitamin premix**	0.10	0.10	0.10
Choline chloride—75%	0.05	0.05	0.05

[1]Each kg of trace mineral mixture contains 100,000 mg manganese, 80,000 mg iron, 80,000 mg zinc, 8,000 mg copper, 200 mg cobalt, 1,000 mg iodine, 150 mg selenium (sodium selenite), 500,000 choline chloride.

[2]Each kg of vitamin mixture contains 13,500,000 IU vitamin A, 4,000,000 IU vitamin D_3, 100,000 mg vitamin E, 5,000 mg vitamin K_3, 3,000 mg vitamin B_1, 8,000 mg vitamin B_2, 60,000 mg niacin, 18,000 mg Ca-D-pantotenate, 5,000 mg vitamin B_6, 30 mg vitamin B_{12}, 2,000 mg folic acid, 200 mg D-biotin, 100,000 mg vitamin C.

Table 2. Nutrient content of the feeds used in the experiment.

Nutrients	Starter feed (1−10 d)	Grower feed (11−24 d)	Finisher feed (25−35 d)
Crude protein (%)	24.00	23.00	21.00
ME (kcal/kg)	3000	3100	3100
Cellulose	3.40	3.40	3.70
Ether extract (%)	4.00	4.00	5.00
Ash (%)	5.30	5.30	4.90
Lysine (%)	0.90	0.90	0.90
Methionine (%)	0.60	0.60	0.60
Calcium (%)	0.90	0.90	0.90
Phosphorus (%)	0.60	0.60	0.60

Measurement of Performance Parameters

Feed intake was calculated as weekly by subtracting the remaining feed at the end of the week from the total feed provided during the week. The live weight gain was also determined by subtracting the weights at the beginning of the trial from the weekly body weight gain. The number of dead animals was recorded on a weekly basis. The feed conversion ratio was calculated by dividing the total feed consumed by the body weight gain.

Broiler chickens were slaughtered at the end of the experiment on d 35. A total of 96 chickens, 32 from each experimental group with 2 males and 2 females from each replicate were slaughtered. After slaughter, the carcasses of male and female chickens were separately weighed and the hot carcass values were recorded. Then the carcasses were stored in a refrigerator at +4°C for 24 h. After the cold storage, the carcasses of the male and female chickens were weighed separately, the cold carcass weight was recorded and the carcass yield was calculated using following formula,

$$\text{Carcass Yield} = (\text{Coldcarcass weight}(g)/\text{Slaughter weight}(g)) \times 100$$

After weighing the abdominal fat, the abdominal fat ratio was determined using following formula,

$$\text{Abdominal Fat Ratio} = (\text{Abdominal fat weight (g)}/\text{Coldcarcass weight(g)}) \times 100$$

Evaluation of the Gait Score and Footpad Dermatitis

The gait scoring of chickens on the 35th day of the experiment was performed using a method proposed by Kestin et al. (1992). Scoring of footpad inflammation was performed by carefully examining the right and left footpads of chickens with the naked eye and given a score between 0 and 2 (the lesion increases as the score gets larger) for lesions and injuries (Ekstrand et al., 1997).

Microbial Analysis of Litter Materials

Litter materials were first chopped and then 10-g of the chopped litter was transferred into a sterile stomacher bag containing a sterile 90 mL 0.85% NaCl physiological solution. Samples were homogenized for 4 min through a BagMixer (Interscience, Model 400P, Saint-Nom-la-Bretèche, France) followed by 2 h of maceration for transmission of microorganisms to the dilution solution. Macerated samples were 10-fold serially diluted, then streaked on selective medium. The medium and the incubation conditions were as follows:

The number of coliform bacteria were enumerated by plating on a Viole Red Bile Agar (**VRBA**) and incubated aerobically at 37°C for 2 d (Muyanja et al., 2003). The amount of *E. coli* in the samples were determined by the standard most probable number (**MPN**) method according to Doğan-Halkman et al. (2003). The total amount of yeast and mold were determined on Potato Dextrose Agar (**PDA**) supplemented with oxytetracycline (100 mg/L) and plates were incubated at 25°C for 3 and 5 d for the growth of yeast and molds, respectively (Campbell, 1988; Ciani et al., 2006). The number of total mesophilic aerobic bacteria (**TMAB**) were enumerated on Plate Count Agar (**PCA**) and plates were incubated at 30°C for 2 to 3 d (Erdogan et al., 2018).

Meat Quality Analysis

The characteristics of the meat quality were determined by pH, cooking loss, color analyses, and texture profile analysis (**TPA**). The pH of the uncooked breast meats was measured using Hanna Instruments HI 99163 meat pH meter. The cooking loss was determined by subtracting the weights determined on the electric grill after cooking (internal temperature of 74°C) from the weight of the uncooked meat obtained using 0.001 g precision scales. The following formula was used to calculate the cooking loss.

$$\text{Cooking loss}(\%) = (\text{weight of uncooked breast meat} - \text{weight of cooked breast meat})/\text{weight of uncooked breast meat}) \times 100$$

A hand-held color measuring device (Konica Minolta, model Cr400, Tokyo, Japan) was used to measure the color of the cooked breast meat and 3 measurements were taken from the outer surface of the uncooked samples. The colorimeter was equipped with an 8 mm aperture size and calibrated with a standard white tile ($Y = 93.7$, $x = 0.3157$, $y = 0.3323$) using the settings of illuminant D-65 and 2° observer. L*, a*, b* color (L*: brightness; a*: redness; b*: yellowness) values were obtained in order to register the color of the samples as numerical values in the Hunterlab coloring system. Warner-Bratzler shear force values were determined using 3 round core samples (1.27 cm in diameter) obtained parallel to the longitudinal orientation of the fibers from uncooked breast samples. In addition, using 3 round core samples (1.27 cm in diameter, 1 cm height) of the cooked meat samples, hardness, adhesiveness, cohesiveness, chewiness, resilience and springiness were determined with texture profile analysis (**TPA**). The properties that were evaluated using TPA are defined below according to the definition provided by Paredes et al. (2022).

- Hardness is the maximum force of the first compression.
- Cohesiveness is how well the product withstands a second deformation relative to its resistance under the first deformation.

- Chewiness is defined as the Gumminess × Springiness. It can be interpreted as the energy required to chew a solid food.
- Resilience is how well a product "fights to regain its original height."
- Springiness is the height at which food can recover between the end of the first bite and the beginning of the second bite.

These processes were carried out using a texture analyzer (TA-XT Plus, Stabile Microsystems, London, UK) and an aluminum probe with a diameter of 50 mm was used to compress the meat samples. Pretest speed (1.0 mm/s), test speed (2.0 mm/s), and post-test speed (10.0 mm/s) were used to compress samples axially in a double compression cycle to 50% of their initial height.

Statistical Analysis

The data obtained from the experiment were analyzed using SAS package program. The analysis of variance was carried out using the general linear model (PROC **GLM**) according to the random plots trial design. Duncan test was used for multiple comparison of means.

RESULTS AND DISCUSSION

Microbial Load of Litter Materials

The microbial loads of the different types of litter materials analyzed at the beginning and the end of the trial are shown in Table 3. At the beginning of the experiment, the number of microorganisms in litter materials differed depending on the litter type. At the end of the study, it was observed that all microorganisms were significantly higher ($P < 0.01$) in rice hull except for total yeast.

Differences among the microbial load of the litter materials prior to the experiment were thought to vary depending on the source of the litter material or the storage conditions. The presence of moisture in the litter materials and antimicrobial compounds in their content were also affected by the presence of microorganisms. The humidity and ventilation level of the environment where the litter material was stored and the moisture content of the litter material were very important factors influencing the microbial load of the litter material (Şekeroğlu et al., 2013).

The microbial load of the litter material at the end of the trial was also affected by several factors including type of the animal, age of the animal, intestinal flora of the animal, and the feed consumed by the animal. The growth of microorganisms in litter materials occurs in the presence of fermentable organic matter and moisture (Senaratna et al., 2007). Among the litter materials used in this study, rice hull was expected to have the lowest microbial load since it had the lowest moisture content due to its ability to dry faster. Also, since thin and thick sawdust was susceptible to caking and leading high moisture content, they were expected to have a higher microbial load. However, the results of this current study were opposite to what was described above.

The microbial load of a litter material was also affected by the type of plant used (Aktan and Sagdic, 2004; Torok et al., 2009). The antimicrobial properties of resins in the trees which were the source of thick and fine sawdust may not have allowed the growth of microorganisms when used as a litter material. Also, Milling et al. (2005) stated that sawdust may exhibit antimicrobial properties due to its hygroscopic feature and the extracts it contains. In a study of conducted by Milling et al. (2005) where pine, larch, maple shavings, and plastic chips inoculated with chicken manure were used as litter materials, the authors concluded that enterobacteria, enterococci, and streptococci species had lower viability on sawdust. On the other hand, Fries et al. (2005) did not observe any significant difference in the microbial load of litter among the different litter materials used in their study. It was also stated that these 2 different findings may be partially due to different microbial culturing techniques (Torok et al., 2009).

Performance Values of Chicks

The effect of different litter materials on the performance of broiler chickens is represented in Table 4.

Table 3. Microbial loads of litter materials at the beginning and end of the trial.

Parameter	Experimental groups TS	FS	RH	SED	P
Micro-organisms (at the beginning of the trial)					
Coliform bacteria	3.84[c]	6.90[a]	4.15[b]	0.233	<0.001
E. coli bacteria	3.04[c]	5.56[a]	3.55[b]	0.011	<0.001
Total yeast	5.76[b]	8.04[a]	5.04[c]	0.008	<0.001
Total mold	5.77[a]	4.00[ab]	3.60[b]	0.339	0.083
Total mesophilic aerobic bacteria	6.47[c]	8.43[a]	6.69[b]	0.010	<0.001
Micro-organisms (at the end of the trial)					
Coliform bacteria	7.35[b]	7.39[b]	7.50[a]	0.013	0.007
E. coli bacteria	5.80[c]	5.88[b]	5.97[a]	0.011	0.003
Total yeast	9.07[a]	8.87[b]	8.90[b]	0.011	0.001
Total mold	5.17[b]	5.84[a]	4.30[c]	0.017	<0.001
Total mesophilic aerobic bacteria	10.33[b]	10.40[b]	10.59[a]	0.012	<0.001

[a,b]Significant of interaction effect on group averages indicated by different letters ($P < 0.05$).Abbreviations: FS, fine sawdust; RH, rice hull; TS, thick sawdust.

There were no statistical difference among the treatment groups in terms of body weight gain and the number of mortality. It was observed that use of thick sawdust, fine sawdust, or rice hull as litter materials had no significant effect on body weight gain during the study. Similarly, Asaniyan et al. (2007) used wood shavings or sand as a litter material at different depths and concluded that the average body weight gain was not affected by the type of litter material or its depth. In addition, Kueile et al. (2019) also did not observe any significant difference on body weight gain when animals were reared on different litter materials (wood chips, dry pine leaves, used barn litter, and sand). Costa et al. (2021) also reported that the use of thick sawdust or rice straw in 2 different stocking densities had no significant effect on live weight gain and slaughter weight. Likewise, Dhaliwal et al. (2018) concluded that animals reared on rice hull and thick wheat straw had similar body weight.

Toghyani et al. (2010) observed that broiler chickens reared on rice hull had lower body weight gain compared to other groups. In another research conducted by Gupta et al. (2020), rice hull, rice hull + rice straw, and thick sawdust were used as litter materials and the authors observed that body weight gain was higher in the mixed group (rice hull + rice straw) compared to the others. Furthermore, Munir et al. (2019) stated that litter materials affect body weight gain; however, wood-based litter material had no negative effect on weight gain. In general, the similar body weight recorded between the groups might explain the fact that use of different litter materials and depth of the litter material had no effect on performance of chicks as long as birds' mobility were not restricted for reaching feed and water.

During the first 2 wk of the experiment, there were no significant differences in terms of feed consumption between groups however, the highest feed consumption ($P < 0.05$) was observed in the group reared on rice hull during the third week of the experiment. Similar to the current study, Anisuzzaman and Chowdhury (1996), Singh and Sharma (2000), as well as Soliman and Hassan (2020) stated that animals reared on rice hull had better feed consumption rate compared to those reared on sawdust. Contrary to the above studies, Toghyani et al. (2010) observed that animals reared on rice hull had the lowest feed consumption. In addition, Abougabal et al. (2022) also recorded the lowest feed consumption rate in animals reared on rice hull. However, the general opinion was that, the use of sawdust or rice hull as litter materials did not have any significant effect on feed consumption rate (Garces et al., 2017; Kuleile et al., 2019; Gupta et al., 2020). Peacock et al. (1984) stated that the live weight gains of the chicks were deteriorated by consuming small litter materials. In the current study, the consumption of small particles of litter materials other than rice hull by the chicks may have caused the digestive system (crop) to be full thereby suppressing further feed consumption. It assumed that the structure (sharpness and hardness) of the rice hull might have made it difficult to be swallowed by chicks thereby not affecting the feed consumption rate of animals.

Several authors (Asaniyan et al., 2007; Toghyani et al., 2010; Petek et al., 2014; Garces et al., 2017; Kuleile et al., 2019) have stated that rearing broiler chickens on either sawdust, sand, rice hulls, or in a litterless system had no significant effect on feed conversion ratio. Atencio et al. (2010) also reported that chickens reared on rice hull had the best feed conversion ratio compared to those reared on other litter materials. In contrast, Gupta et al. (2020) reported that the animals reared only on rice hull had the poorest feed conversion ratio which is similar to the findings in the current study.

Feed conversion ratio in broilers can be defined as the ability of a bird to convert nutrients from the feed into the body weight gain; however, some of these nutrients are also used for performing other activities such as movement. The wood-based litter material used in this study started to cake or clump together with time which worsened the litter quality, thereby causing foot problems (inflammation of the feet) and restriction of movement. On the other hand, animals reared on rice hull had fewer foot problems due to the ability of the rice hull to absorb water as well as its ability to dry at a faster rate, thereby not forming cakes or clumping together. For this reason, the animals reared on rice hull spent more energy as they were more active, causing their feed conversion ratio to be poorer.

Similar to the current study, other trials (Toghyani et al., 2010; Petek et al., 2014; Garces et al., 2017; Kuleile et al., 2019) did not observe any significant effect of the litter materials on mortality among any of the experimental groups. Mortality might occur when animals are not able to access feed and water due to excessive foot inflammation or respiratory tract infections as a result of poor quality of the litter material. In the current study, use of relatively lower number of animals coupled with good ventilation resulted in lower and similar mortality rate among the groups.

Carcass Characteristics of Chicks

The effect of the litter materials on the carcass characteristics is presented in Table 5. It was observed that the litter materials did not have any significant effect on either of the characteristics of the carcass.

It was reported that chickens reared on rice hull had the lowest body weight at slaughter compared to those reared on other litter materials (Toghyani et al., 2010; Petek et al., 2014). Garces et al. (2017) indicated that animals reared on Guinea grass had the poorest weight at slaughter. However, similar to the current study, the authors did not observe any significant difference in terms of body weight among those reared on sawdust and rice hull. The similarities between the body weight gains of the animals during the study expressed itself in the slaughter weight as expected.

The effect of different litter materials such as thick sawdust, fine sawdust, sand, or rice hull on carcass parameters such as hot carcass weight, carcass yield, and abdominal fat were also found to be not significant

Table 4. Effects of different litter materials on performance parameters.

	Experimental groups				
Parameter	TS	FS	RH	SED	*P*
BW0 (g)	44.38	44.38	44.36	0.034	0.966
Cumulative body weight gain (BWG, g)					
BWG1	147.22	149.33	144.22	1.460	0.374
BWG2	480.14	480.85	454.94	6.791	0.231
BWG3	968.13	976.08	965.40	8.922	0.880
BWG4	1503.42	1548.14	1500.49	11.984	0.215
BWG5	1883.47	1952.03	1920.85	11.523	0.074
Cumulative feed intake (FI, g)					
FI1	196.06	196.26	197.06	1.219	0.939
FI2	584.57	560.85	574.82	7.950	0.485
FI3	1238.16[ab]	1202.99[b]	1282.52[a]	11.746	0.038
FI4	2102.95[ab]	2008.28[b]	2221.92[a]	24.205	0.006
FI5	3097.10[ab]	2990.80[b]	3393.40[a]	65.295	0.053
Cumulative feed conversion ratio (FCR)					
FCR1	1.34	1.32	1.37	0.015	0.424
FCR2	1.22	1.17	1.27	0.019	0.134
FCR3	1.28[ab]	1.23[b]	1.33[a]	0.012	0.021
FCR4	1.40[a]	1.30[b]	1.48[a]	0.017	0.001
FCR5	1.65[ab]	1.53[b]	1.77[a]	0.036	0.051
Cumulative number of mortality (MN, piece)					
MN1	0.13	0.25	0.50	0.112	0.399
MN2	0.13	0.38	0.75	0.128	0.158
MN3	0.25	0.50	1.00	0.151	0.144
MN4	1.00	0.88	1.75	0.220	0.237
MN5	1.75	1.75	2.38	0.278	0.578

[a,b]Significant of interaction effect on group averages indicated by different letters ($P < 0.05$).Abbreviations: FS, fine sawdust; RH, rice hull; TS, thick sawdust.

by previous authors (Billgilli et al., 1999; Asaniyan et al., 2007; Toghyani et al., 2010; Onu et al., 2011).

The Gait Score and Footpad Dermatitis in Chicks

The gait score and footpad dermatitis of broiler chickens reared on different litter materials are presented in Table 6. While the effect of litter material on gait scores in female and male chickens was not significant, the effect on footpad dermatitis was significant ($P < 0.001$).

It is generally accepted that hard litter materials causes foot problems. Davis et al. (2010) also reported that use of millet as a litter material instead of pine chips reduced foot problems. Petek et al. (2014) on the other hand reported that the use of rice hull increased foot lesions compared to thick sawdust. Kuleile et al. (2019) also observed that use of dried pine leaves and decomposed corral mats as an alternative litter material to thick wood shavings significantly increased footpad dermatitis. However, in the current study, the thick and fine sawdust litter materials had the poorest water absorbing capacity which worsened the litter quality in the subsequent weeks. Also, the ammonia level of the litter materials increased as the moisture content of the litter material increased following weeks. So it was thought that the footpad dermatitis and gait score values deteriorated for this reason, especially in the fine sawdust group, which was highly susceptible to caking. As the moisture contents of litters could not be analyzed in the study, unfortunately no comment and discussion would be made on the relations between gait and also footpad inflammation scores with the moisture of litter. However, in broiler production, it is well known that increasing the moisture in litter leads to increase in footpad score (Martland, 1985; Mayne, 2005; Taira et al., 2014).

Meat Quality of Chicks

The pH and color of the breast meat, water loss during cooking, Warner-Bratzler shear force of cooked meats, and TPA analysis results are presented in Table 7. With

Table 5. Effects of different litter materials on carcass characteristics.

	Experimental groups				
Parameter	TS	FS	RH	SED	*P*
Slaughter weight (g)	1990.09	2038.41	1978.06	16.253	0.281
Hot carcass weight (g)	1544.63	1570.56	1531.00	13.232	0.466
Cold carcass weight (g)	1498.38	1524.19	1483.69	12.761	0.426
Carcass yield (%)	75.31	74.76	75.00	0.481	0.486
Abdominal fat weight (g)	17.22	17.42	16.37	0.185	0.639
Abdominal fat rate (%)	1.15	1.14	1.11	0.031	0.850

Abbreviations: FS, fine sawdust; RH, rice hull; TS, thick sawdust.

Table 6. The effect of litter materials on footpad dermatitis.

	Experimental groups				
Parameter	TS	FS	RH	SED	P
The gait score and footpad dermatitis					
Gait score (males)	2.46	2.83	2.72	0.066	0.072
Gait score (females)	2.22	2.29	2.15	0.070	0.718
Gait score (females + males)	2.43	2.53	2.38	0.050	0.454
Inflammation (males)	0.18[b]	0.76[a]	0.01[b]	0.037	<0.001
Inflammation (females)	0.21[b]	0.55[a]	0.08[b]	0.032	<0.001
Inflammation (females + males)	0.20[b]	0.66[a]	0.05[c]	0.025	<0.001

[a,b,c]Significant of interaction effect on group averages indicated by different letters ($P < 0.05$).
Abbreviations: FS, fine sawdust; RH, rice hull; TS, thick sawdust.

Table 7. The effect of litter materials on meat quality.

	Experimental groups				
Parameter	TS	FS	RH	SED	P
Water loss	37.16[a]	27.47[b]	26.54[b]	0.592	<0.001
pH	5.84	5.87	5.85	0.009	0.418
Color					
L*	61.94	60.98	61.44	0.245	0.279
a*	1.13	1.55	1.16	0.087	0.087
b*	4.81	4.66	4.28	0.120	0.189
Chroma	5.03	5.04	4.55	0.121	0.170
Hue	62.29	62.71	51.99	3.725	0.415
Cutting strength (uncooked)	5.82	6.08	5.93	0.138	0.740
Texture profile analysis (TPA)					
Hardness	19.04[a]	16.64[b]	17.88[ab]	0.334	0.015
Springiness	0.56[b]	0.56[b]	0.58[a]	0.003	0.024
Cohesiveness	0.56	0.54	0.56	0.004	0.141
Chewiness	5.64[a]	5.04[b]	6.16[a]	0.119	0.001
Resilience	0.22	0.21	0.22	0.002	0.286

[a,b]Significant of interaction effect on group averages indicated by different letters ($P < 0.05$).
Abbreviations: FS, fine sawdust; RH, rice hull; TS, thick sawdust.

regards to the meat, no significant difference in terms of pH, color and TPA analysis (cohesiveness and resilience) was observed. However, water loss during cooking was highest in the group reared on thick sawdust, and it was also observed that there was a significant difference ($P < 0.05$) between the treatment groups in terms of hardness, springiness and chewiness.

Generally, the animals spend most of their time lying on the chest due to the absence of a perches in the broiler houses. So, the quality of the litter material plays an important role in the quality of the breast meat. The accumulation of ammonia in litter causes inflammation and bruising of breast meat, thus reducing the meat quality (Şekeroğlu et al., 2013). It was also expected that the quality of wood-based litter materials would deteriorate more rapidly due to caking, which would also reduce the quality of the breast meat (especially the color values including L* a* b*). However, in the current study, it was thought that use of relatively small number of animals coupled with good ventilation decreased the likelihood of this problem by preventing the accumulation of ammonia in the litter materials. On the other hand, stress in preslaughter animals causes excessive secretion of epinephrine from the adrenal glands and a rapid breakdown of glycogen in body reserves. As a result of this event, a reduction in pH was observed due to the accumulation of lactic acid in the muscles (Bozzo et al., 2018). Hertanto et al. (2018) stated that pH after slaughter under normal conditions ranged between 5.3 and 6.5. If the preslaughter stress lasts for a long time, the production of lactic acid stops which is followed by the depletion of glycogen. Lactic acid is then metabolized by the liver and heart, and the pH value of the meat begins to rise again. If the pH value of the meat after slaughter is lower than 5.6, it is termed as pale-soft-exudative (**PSE**) and if it is higher than 6.4 it is also referred to as dark-firm-dry (**DFD**) meat defects. In addition, a meat with a pH value outside the normal range has a very pale or dark color, a hard or soft and sweaty texture with a very high or low water-holding capacity. The pH values obtained from this study are in agreement with the previous values obtained from other studies mentioned above. Regardless of the litter type, subjecting animals to standard slaughtering conditions without wasting time prevents changes among the measured pH values, and thus, similar pH values were obtained among all the experimental groups.

CONCLUSIONS

It was concluded that the use of thick sawdust, fine sawdust, or rice hull as litter materials in current experiment did not affect the body weight gain, mortality, carcass parameters, or gait score as well as the pH, color, cohesiveness, and resilience of the breast meat. However, the use of rice hull as a litter material increased feed intake and the microbial load of litter. Although fine sawdust as a litter material increased footpad dermatitis, it did not adversely affect the performance of animals since the FCR of this group was much better compared to the other groups. With the results obtained from this study, it can be suggested that use of fine sawdust from trees such as pine and larch would be more appropriate as litter materials in the production of broiler chickens.

DISCLOSURES

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in the present study.

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