

Charcoal treated cassava peel litter properties and their effects on physiological, welfare, caecal bacteria counts and carcass traits of broiler chickens

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Abstract

The search for sustainable alternative litter material for broiler production resulted in a 6-week study investigating the effects of alternative litter material - wood shavings (WS) and charcoal treated cassava peel (CPC) as litter material, in various ratios, on litter physicochemical traits, physiological traits, welfare parameters, carcass characteristics and caecal bacteria counts of Arbor Acres Plus broiler chickens. There were five treatments: 100%WS, 75%WS:25%CPC, 50%WS:50%CPC, 25%WS:75%CPC, and 100% CPC. Litter samples were collected once every two weeks for analysis of litter physicochemical traits (pH, moisture %, ammonia concentration and bulk density). Physiological traits (rectal temperature, respiratory rate, heart rate) of birds were also evaluated once at the end of every two weeks. On day 42, welfare parameters (footpad lesion, hock burn, breast blister, feather cleanliness, lameness) of birds were determined. After excising bird carcass, samples were collected from birds' caecum for investigation of bacteria count and carcass characteristics were also determined. Results showed there were no significant differences ($p > 0.05$) observed across treatments for any of the traits considered. This suggests that the physicochemical traits of charcoal treated cassava peel as alternative litter was comparable to that of wood shavings. The litter types alone or in ratio combinations did not compromise physiological traits, welfare parameters, carcass characteristics and caecal bacteria counts of broilers at 6 weeks old.

Keywords: Litter, cassava peels, charcoal, physiological, welfare, broiler chickens

Propriétés de la litière à base d'écorces de manioc traitées au charbon de bois et leurs effets sur les paramètres physiologiques, le bien-être, la densité bactérienne cœcale et les caractéristiques des carcasses chez les poulets de chair



Résumé

La recherche d'une litière alternative durable pour la production de poulets de chair a donné lieu à une étude de six semaines visant à évaluer les effets de deux litières alternatives – les copeaux de bois (WS) et les écorces de manioc traitées au charbon de bois (CPC) – utilisées dans différents rapports, sur les caractéristiques physico-chimiques de la litière, les paramètres physiologiques, les indicateurs de bien-être, les caractéristiques des carcasses et la densité bactérienne cœcale chez des poulets de chair de la lignée Arbor Acres Plus. Cinq traitements ont été mis en place : 100 % WS, 75 % WS : 25 % CPC, 50 % WS : 50 % CPC, 25 % WS : 75 % CPC et 100 % CPC. Des échantillons de litière ont été prélevés toutes les deux semaines afin d'analyser les caractéristiques physico-chimiques de la litière (pH, taux d'humidité, concentration en ammoniac et densité apparente). Les paramètres physiologiques (température rectale, fréquence respiratoire, fréquence cardiaque) des volailles ont également été évalués une fois toutes les deux semaines. Au 42^e jour, les paramètres de bien-être (lésions des pattes, brûlures au jarret, cloques sur la poitrine, propreté du plumage, boiterie) des volailles ont été déterminés. Après le dépeçage des volailles, des échantillons ont été prélevés dans le cœcum des oiseaux afin de déterminer la charge bactérienne, et les caractéristiques des carcasses ont également été évaluées. Les résultats ont montré qu'aucune

différence significative ($p > 0,05$) n'avait été observée entre les différents traitements pour aucun des paramètres étudiés. Cela suggère que les caractéristiques physico-chimiques des épluchures de manioc traitées au charbon de bois, utilisées comme litière alternative, étaient comparables à celles des copeaux de bois. Les types de litière, utilisés seuls ou en combinaisons proportionnelles, n'ont pas altéré les caractéristiques physiologiques, les paramètres de bien-être, les caractéristiques des carcasses ni la charge bactérienne cæcale des poulets de chair âgés de 6 semaines.

Mots-clés : Litière, épluchures de manioc, charbon de bois, physiologie, bien-être, poulets de chair

Introduction

A key sub-sector of the agricultural industry in Nigeria is the poultry industry and according to (Ewubare and Ozar, 2018), popularity of poultry birds in Nigeria is noteworthy and can be attributed to the numerous benefits associated with poultry production and other value chain. Poultry health and welfare, food safety, and environmental maintenance requirements are ensured at optimal levels with the use of litter (Yeter, 2021). Litter or bedding material is used in the poultry house to provide comfortable environmental conditions as well as to achieve optimum productive performances (Hossain *et al.*, 2018). In intensive commercial broiler production, birds are reared with the use of different litter material types on the floor (Taherpavar *et al.*, 2016), and examples include wood shavings, sawdust, rice husk/hulls, sugarcane bagasse, wheat straw, soybean residue, corn cobs or stover, silage, peanut hulls, refused tea, guinea grass, clover, dried pine leaves and inorganic materials like sand and clay (Hafeez *et al.*, 2009; Thennakoon *et al.*, 2024; Escobar *et al.*, 2024). Several studies have suggested different litter materials for use in poultry production including paddy husk, chopped paddy straw (Merentula *et al.*, 2023), decomposed kraal manure, sand (Kuleile, 2019), waste paper sludge (Yeter, 2021), chopped *Panicum maximum* (Oke *et al.*, 2019) and neem leaves (Bishnoi *et al.*, 2021).

As poultry concentration increases in Nigeria, appreciating the influence of litter materials on which poultry birds are reared has become vital (Ayeni *et al.*, 2018). A study by De Jong *et al.* (2014) confirmed there is a strong effect of foot pad dermatitis (FPD) caused by wet litter on

poultry performance and their welfare. They declared that FPD occurrence reduces bird mobility, causing hock burns and breast blisters and having significant negative effect on the birds. The occurrence of lesions on birds reduces their carcass quality and as Hossain *et al.* (2018) reports, various litter materials can aggravate the occurrence of lesions primarily on chicken breasts and footpads because of high moisture content or humidity levels. The quality of litter is of great concern in broiler production because it affects performance, health, carcass quality and the welfare of broilers (Abo-Talib, *et al.*, 2024), thus investigating alternative sources of litter bedding material for sustainable environmental and poultry production especially broilers becomes imperative. A number of alternative bedding materials derived from recycled materials from the wood and paper industries and by-products of crop industries have been proposed (Gerber *et al.*, 2020).

Cassava peels are a major by-product of cassava tuberous root processing industry which is largely under-utilized (Eyoh *et al.*, 2019). Fasae and Yusuf (2022) reported that cassava peel is obtained during the processing of cassava tuber to starch. It consists of thin skin and leathery parenchymatous covering, with some pieces of cassava root tuber in their lining, constituting about 15% - 20% of the tuber. In a study conducted by Ayeni *et al.* (2018), chickens could be reared up to 56 days of age using any of the tested litter materials including cassava peels without any adverse effect on the weight changes and feed consumption of birds. Another by-product is charcoal, a common by-product of fuel generation. It can be an alternative that is cheap, accessible, and all-natural. A previous study

(Farghly *et al.*, 2022) evaluated airborne and litter conditions in housing of broiler chickens as affected by charcoal treated litters (wood shavings and sand). The conclusion was addition of charcoal (crumbles or pellets) to sand litter decreased litter moisture and ammonia levels compared to wood shavings litter. In Nigeria, cassava peel is readily available (Akindele *et al.*, 2025) and charcoal is available in all the country's geopolitical zones as many local communities have perfected the technology of charcoal production (Odunayo *et al.*, 2019). Optimal litter conditions allow birds to exhibit their natural behaviors, promoting their overall well-being without emitting harmful levels of ammonia. An ideal litter material for poultry production should be dry, highly moisture-absorbent, quick to release moisture, adequately porous, and non-toxic to birds (Thennakoon *et al.*, 2024). Wood shavings are reported to possess high water-holding capacity, resulting in litter quality that is better than litter materials with absorption capacity that is poorer (like straw). Thus, controlling bird environment, especially humidity, ammonia and litter moisture is vital in provision of good welfare (Petek *et al.*, 2014). Information is limited on the use of cassava peels as litter in poultry production, especially when combined with charcoal crumbles collected as waste after cooking. Hence, the current study was designed to investigate the physicochemical properties of charcoal treated cassava peel as litter material and their effects on, physiological traits, welfare parameters, carcass characteristics and caecal bacteria counts of broiler chickens.

Materials and methods

Experimental site

The experiment was carried out in an open-sided pen from June to August 2025 at the Poultry Unit, Institute of Food Security, Environmental Resources and Agricultural Research (IFSERAR), Federal University of Agriculture, Abeokuta (FUNAAB), Ogun State, Nigeria. The site lies within Latitude 7.2303°N and Longitude

3.3991°E at an altitude of 130 meters above sea level in Odeda Local Government, Ogun State (GPS app, 2025). The mean annual rainfall of the area is 1,113 mm. Mean monthly temperature varies from 22.94°C in August to 36.32°C in March. The relative humidity ranges from 75.52% in February to 88.15% in July (Olaiya *et al.*, 2015).

Source of litter materials

Cassava peels were sourced from the Cassava/Garri Processing Unit at the Directorate of University Farms (DUFARMS) in FUNAAB and from a nearby community in Odeda Local Government Area of Ogun State. The cassava peels were sorted in order to remove the stumps or whole cassava, debris, and other dirt that may be present in the peels. They were sundried until a constant weight was attained. Wood shavings was purchased from wood workshops and sawmills situated within Odeda Local Government area, Abeokuta in Ogun State. Charcoal crumbles that was left over after burning of wood, from the ovens of a local bakery (located in a community in Odeda Local Government) was also collected, dried and stored in dry aerated bags before use.

Experimental birds and management

Two hundred and forty day-old broiler chicks (Arbor Acres Plus) were purchased and raised in a deep litter system and were brooded in the first two weeks of arrival. The pens were washed, allowed to dry, and then litter materials were spread out at a depth of 5 cm in the pens according to the respective treatments. At arrival, chicks were weighed using a digital weighing scale and distributed randomly into different experimental cells. For litter, the cassava peels were mixed with charcoal crumbles which was introduced to enhance the physicochemical properties and functionality of the cassava peels as litter material. There was no established procedure for this combination identified in literature. This procedure was designed specifically for the present experiment. Charcoal

crumbles were included proportionally according to the ratio of cassava peels. At 100% ratio the cassava peels measured 8.65kg but, this measure reduced as wood shavings was combined at different ratios. The proportions of charcoal crumbles was included to the charcoal peels as follows: Treatment (TRT) 1= 0 kg; TRT 2= 0.335 kg; TRT 3= 0.675 kg; TRT 4= 0.125 kg; TRT 5: 1.35 kg of charcoal crumbles in each treatment group. The cassava peels with charcoal crumbles and wood shavings were spread out evenly on the floor of experimental pens. Vaccinations and medications were administered following a recommended schedule, and the birds were given water and feed *ad-libitum* throughout the experimental period.

Experimental design

The experiment was laid out in a completely randomized design (CRD), and the 240 birds were randomly allotted into five experimental treatments with 4 replicates of 12 birds each. The experimental treatments were as follows:

Treatment 1: 100% Wood Shavings (WS) (Control Treatment) - 100%WS

Treatment 2: 75% Wood Shavings (WS) and 25% cassava peels with charcoal (CPC) - 75%WS:25%CPC

Treatment 3: 50% Wood Shavings (WS) and 50% cassava peels with charcoal (CPC) - 50%WS:50%CPC

Treatment 4: 25% Wood Shavings (WS) and 75% cassava peels with charcoal (CPC) - 25%WS:75%CPC

Treatment 5: 100% Cassava peels with charcoal (CPC) - 100% CPC

Data collection

The following physicochemical properties of litter was determined at the end of every 2 weeks at the Department of Soil Science Laboratory, Federal University of Agriculture Abeokuta:

Litter pH: Samples were taken randomly from three different locations in each replicate, pooled together and taken to the laboratory where a pH meter was used to determine pH values of litter

from each replicate. **Litter moisture (%):** Samples were taken randomly from three different locations in each replicate and oven dried at 70°C until constant weight. Moisture percentage content was determined based on the difference between the initial weight and the dried weight of the samples.

Ammonia (NH₃) concentration: This was determined with the use of a portable ammonia gas meter (GOYERRNES, GR-US-535G), with a measurement range of 0-100 ppm and a resolution of 0.1 ppm. The device was placed at nostril level of birds in two different locations in each replicate pen (Duman *et al.*, 2024). It was determined bi-weekly. Readings were shown on the screen of the device and the values for ammonia concentration was recorded.

Bulk density: Samples were taken randomly from three different locations in each replicate, pooled and filled into a container until the container was full and packed firmly (Merentula *et al.*, 2023). The sample was weighed with the measured container, then empty container weight was subtracted to get the net weight of litter. Bulk density standard formula is expressed in g/m³. Bulk density = Mass of built up litter / Volume of container

Where:

Mass of built up litter = Weight of the built up litter material – weight of container

Volume of container= $\pi r^2 h$

Physiological traits of broilers

The physiological traits in broilers were taken once on the second, fourth and sixth week of the experiment:

Rectal temperature: This was determined by inserting a digital thermometer tip into the cloaca of each of three randomly selected chickens per replicate to take readings.

Respiratory rate: This was determined by counting the panting or flank movement of each of three randomly selected chickens per replicate observed for 30 seconds (using a stop watch) and

then multiply by two, which is expressed as breaths per minute.

Heart rate: The heart rate was assessed by placing a stethoscope on the left side just behind the wings of the chicken. Heart sounds were auscultated and counted for 15 seconds using a stopwatch. The readings were multiplied by four to get heart rate per minute.

Welfare parameters

The welfare parameters were considered on the 42nd day of the experiment. Two birds were selected randomly from each replicate and examined. Broilers were visually assessed and scored according to the 0-3 scoring system by Welfare Quality (2009) for plumage cleanliness, gait score, hock burn, footpad lesion and breast lesion. Score 0: normal, healthy or clean; score 1: moderate normal or clean; score 2: moderate dirt, lameness or lesions; score 3: severe.

Carcass analysis

At the end of the sixth week, two birds per replicate of similar body weight close to the average body weight of each replicate were selected for carcass and internal organ weight determination. The birds were fasted for 12 hours before slaughtering. They were bled and scalded in water of 60°C. After defeathering, they were eviscerated and dressed to get the dressed carcass weight. The weight of the cut-up parts (thigh, breast, neck, wing, back, and drumstick), organs (heart, bursa, liver, spleen, proventriculus and gizzard), intestines and abdominal fat pads was determined with a sensitive digital scale and expressed as a percentage of live weight. The percentage of dressed weight was calculated as follows:

Dressing (%) = (Dressed weight (g) / Live weight) × 100%.

Caecal bacteria count

The caeca, which are two blind-ended sacs located at the intersection of the small and large intestines in birds, play an essential role in studies focused on gastrointestinal microbiota and general gut health. For this experiment, caeca was

collected from the excised carcass and fresh caecal contents was obtained using a sterilized spatula to scoop material into clearly labeled, sterile sample containers. Each container was securely sealed and transported in ice packs before being taken to the laboratory to determine bacteria counts.

Enumeration and isolation of bacteria

The bacteria counts of caecal content samples were determined using the pour plate technique. One gram of sample was measured into 9ml of sterile water contained in a test tube and allowed to stand for ten minutes. Afterwards, 1 ml of mixture was used in tenfold serial dilution. From the serially diluted samples, 1 ml was aseptically plated out for total viable counts of bacteria on Nutrient Agar and MacConkey Agar. After inoculation of the sterile media aseptically, they were incubated at 37°C for 24 hours to allow for growth of bacteria. At the end of the incubation periods, distinct colonies were observed and counted. Pure cultures were transferred to agar slants for 72 hours and then stored in the refrigerator for further use (Nwakoby *et al.*, 2021; Majekodunmi and Taofeek, 2025). The counts were expressed as colony forming units per millilitre (cfu/ml).

Data analysis

Welfare parameters scores were analysed through Kruskal-Wallis and significantly different means were separated using Dunn's Test as found in the R statistical tool. All other data from other parameters considered in this study were analyzed using one-way Analysis of Variance (ANOVA) through the General Linear Model (GLM) procedure in the MINITAB '18 statistical package. Where significant differences among means are detected, they were separated using Tukey's test within the same software.

Results

Evaluation of the physicochemical properties of the litter materials showed in Table 1 that there were no significant differences ($p > 0.05$) observed

among the treatments for ammonia concentration, pH, moisture content, and bulk density of the litter materials used in this study. However, numerical increases in ammonia concentration,

pH, moisture content, and bulk density were observed with increasing ratio levels of charcoal treated cassava peels compared to the control treatment with 100% wood shavings.

Table 1. Physicochemical properties of wood shavings and charcoal treated cassava peels litter in broiler chicken production

Parameters	100WS	75WS: 25CPC	50WS: 50CPC	25WS:7 5CPC	100 CPC	SEM	P-value
NH(ppm)	9.67	14.23	16.98	16.41	18.03	3.48	0.493
pH	8.45	8.61	8.72	8.94	8.81	0.12	0.149
Moisture (%)	22.91	28.93	23.33	26.33	30.56	3.91	0.586
Bulk density (g/m ³)	8.00	9.1	8.70	8.90	9.40	0.35	0.148

WS: Wood shavings; CPC: Cassava peel with charcoal; NH: Ammonia concentration

Numerical variations were observed among the treatment groups for physiological traits (Table 2) with birds reared on 100% CPC recording the highest rectal temperature (40.97°C) and birds on 75% WS and 25% CPC having the highest

respiratory rate (71.70 breaths/min) and the highest heart beat (244.59 beats/min). These physiological traits were however not significantly ($P > 0.05$) influenced by the different litter treatments.

Table 2. Effect of charcoal treated cassava peel litter on physiological traits of broiler chickens

Parameters	100WS	75WS: 25CPC	50WS: 50 CPC	25WS: 75CPC	100 CPC	SEM	P-value
RT(°C)	40.74	40.79	40.87	40.69	40.97	0.11	0.434
RR (breaths/min)	66.96	71.70	68.74	65.93	67.70	2.19	0.443
HB (beats/min)	244.10	244.59	241.78	242.22	243.70	5.16	0.993

WS: Wood shavings; CPC: Cassava peel with charcoal; RT: Rectal temperature; RR: Respiratory rate; HB: Heart beat

The effect of the litter materials on the welfare parameters of broiler chickens in this study (Table 3) showed that plumage cleanliness, gait score, hock burn, footpad lesion and breast lesion were not significantly ($P > 0.05$) affected by the different litter treatments. Although numerical differences were observed among the treatment groups, birds reared on 100% CPC recorded the lowest gait score and hock burn score, while birds on 25% WS and 75% CPC had the highest footpad lesion score. All of these values were not significant ($P > 0.05$).

Table 3. Effect of charcoal treated cassava peel litter on welfare parameters of broiler chickens

Parameters	100WS	75WS: 25CPC	50WS: 50CPC	25WS: 75CPC	100CPC	P-value
Plumage cleanliness	2.00±0.00	2.00±0.00	2.00±0.00	2.50±0.58	2.50±0.58	0.129
Gait score	1.75±0.95	1.75±0.95	1.75±0.95	1.75±0.95	1.25±0.50	0.894
Hock burn	1.25±0.50	1.50±0.57	2.25±0.50	1.50±0.57	1.25±0.50	0.145
Footpad lesion	1.50±0.57	2.25±0.50	2.50±0.57	2.75±0.50	1.50±0.57	0.056
Breast Lesion	1.25±0.50	1.25±0.50	1.75±0.95	1.00±0.00	1.25±0.50	0.572

WS: Wood shavings; CPC: Cassava peel with charcoal

The following carcass characteristics: live weight, defeathered weight, dressed weight, dressing percentage, and relative weights of head, neck, back, wing, breast, thigh, drumstick, and shank were not significantly ($p>0.05$) affected by the different litter treatments (Table 4). The

relative weights of the bursa, gizzard, heart, liver, spleen, proventriculus, and abdominal fat were also not significantly ($p>0.05$) affected by the different litter treatments. All of these values were statistically comparable.

Table 4. Effect of charcoal treated cassava peel litter on carcass characteristics of broiler chickens

Parameters	100WS	75WS: 25CPC	50WS: 50CPC	25WS: 75CPC	100C PC	SEM	P-value
Live wt (kg)	3.07	3.15	3.29	3.22	3.27	0.056	0.081
Defeathered (%)	85.75	85.18	85.69	84.46	85.57	0.499	0.373
Dressed wt (kg)	2.39	2.42	2.38	2.41	2.31	0.055	0.710
Dressed (%)	74.59	74.25	74.23	74.13	74.06	0.878	0.994
Head	1.98	1.98	2.13	1.98	2.07	0.057	0.276
Neck	4.18	4.67	4.47	4.18	4.33	0.151	0.164
Back	13.48	13.62	14.16	13.55	14.15	0.403	0.610
Wing	7.43	7.61	7.46	7.87	7.78	0.190	0.413
Breast	31.36	30.43	30.55	30.38	30.84	0.591	0.764
Thigh	11.91	11.09	11.39	11.35	11.06	0.241	0.143
Drumstick	9.62	10.73	10.56	10.14	10.08	0.284	0.094
Shank	3.69	3.88	3.94	3.86	3.66	0.076	0.071
Bursa	0.04	0.08	0.07	0.07	0.07	0.007	0.093
Gizzard	1.64	1.86	1.43	1.49	1.59	0.120	0.169
Heart	0.05	0.06	0.04	0.05	0.05	0.004	0.245
Liver	1.62	1.43	1.61	1.69	1.44	0.089	0.207
Spleen	0.09	0.08	0.08	0.08	0.09	0.004	0.075
Proventriculus	0.50	0.36	0.35	0.43	0.46	0.052	0.268
Abdomen fat	0.62	0.71	0.62	0.64	0.90	0.075	0.092

WS: Wood shavings; CPC: Cassava peel with charcoal

The effect of alternative litter material on the caecal bacterial count of broiler chickens showed (Table 5) that total bacterial count was not significantly ($p>0.05$) affected, with values ranging from 4.15 to 5.00 log CFU/g. Various bacterial species, including *Staphylococcus aureus*, *Escherichia coli*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Bacillus subtilis*,

Proteus vulgaris, *Salmonella enterica*, *Campylobacter jejuni* and *Shigella dysenteriae*, were isolated across the treatment groups in varying frequencies.

Table 5. Effect of charcoal treated cassava peels litter on caecal bacterial count in broiler chickens

Parameters	100WS	75WS: 25CPC	50WS: 50CPC	25WS: 75CPC	100CPC	SEM	P- VALUE
Total bacteria count (10^6 cfu/mL)	5.0	4.5	4.15	4.65	4.45	0.38	0.805
<i>Staphylococcus aureus</i>	2.0	2.2	2.1	1.6	2.4	-	-
<i>Escherichia coli</i>	1.7	1.8	1.6	1.65	2.1	-	-
<i>Klebsiella pneumonia</i>	1.2	-	1.3	-	1.7	-	-
<i>Pseudomonas aeruginosa</i>	1.4	-	-	1.4	1.6	-	-
<i>Bacillus subtilis</i>	-	1.6	-	0.6	-	-	-
<i>Proteus vulgaris</i>	-	1.0	-	-	-	-	-
<i>Salmonella enterica</i>	-	-	1.4	-	-	-	-
<i>Campylobacter jejuni</i>	-	-	0.9	-	1.1	-	-
<i>Shigella dysenteriae</i>	-	-	-	0.8	-	-	-

WS= Wood shavings, CPC= Cassava Peels with charcoal, SEM=Standard error of mean,

Discussion

In the present study, litter properties such as ammonia, pH, moisture content, and bulk density did not vary among the treatment groups consisting of wood shavings and the alternative litter, charcoal treated cassava peels applied either singly or in varying ratios. This agrees with Şen *et al.* (2023) who observed there were no differences between wood shaving and barley straw either used alone or in a mixed ratio in terms of ammonia level and moisture content. In another study, litter pH showed no differences were observed among river bed sand, coconut

husk, rice hull, guinea grass, newspaper combined with wood shavings, and corn cob as litter materials (Garcês *et al.*, 2013). There was no significant difference among bedding material treatments in terms of their effects on litter pH, ammonia concentrations, and moisture levels (Yeter, 2021). Tan *et al.* (2019) confirmed that some organic materials possess ammonia-inhibiting properties, ensuring better litter quality materials. However, the ratio of wood shavings to charcoal treated cassava peels as alternative litter material in this study may not have such properties. In contrast to this study however,

Petek *et al.* (2014) reported a higher moisture percentage in wood shavings than in rice hull litter material. According to Dunlop *et al.* (2016), ideal litter material should have a pH of 8-10, and ammonia content should not exceed 25ppm. The values for pH and ammonia even though not significant in this study fell within these ranges. In intensive deep-litter systems, broiler chicken welfare and productivity rely heavily on effective thermal regulation and respiratory stability (Apalowo *et al.*, 2024). While physiological traits did not differ significantly across litter treatments in this study, recorded rectal temperatures were within the standard physiological range previously established for broiler chickens (Fitra *et al.*, 2017)

In agreement with the findings of this current study, Ramadan and El-Khloya (2017) reported that litter type had no effect on the parameters considered. In addition, Farghaly (2012) noted that foot pad burns, hock discoloration and breast blisters scores were not significantly affected in turkeys reared on wheat straw litter, clover and corn stalks straw. Furthermore, Benabdeljelil and Ayachi (1996) found no effect of litter types on plumage scoring, breast blisters, leg abnormalities and footpad lesions of broiler chicks reared on ground rice straw, wood shavings, sawdust or rice hull. Previous studies (Sigroha *et al.*, 2017; Zikic *et al.*, 2017) have reported foot and breast defects and significant effects on other welfare parameters by litter material. Also, Tercic *et al.* (2015) reported significant differences in FPD scores for wood shavings (1.00), shredded paper (1.15), and chopped wheat-straw pad litter (1.48). Yamak *et al.* (2016) 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 higher litter moisture and ammonia levels. Thus the lack of significant effect on foot pad or other welfare parameters in this study can be attributed to the levels of moisture and ammonia

in the litter material considered in this study not being sufficient to elicit an effect.

Farhadi (2014) indicated previously that lungs, thigh and intestinal weight were not significantly affected by litter material types and this agrees with this current study's result. Atapattu and Wickramasinghe (2007) and Grimes (2004) did not observe significant effect of litter material type on carcass characteristics. According to Grimes *et al.* (2002), litter materials that effectively control moisture and ammonia levels help maintain normal growth and carcass yield in broilers. The consistency in dressed percentage (74.06–74.59%) across treatments indicates that carcass yield was not influenced by the variation in bedding materials. This implies that charcoal treated cassava peels litter were comparable to wood shavings in supporting optimal growth conditions.

The caecum is a major site of bacterial fermentation in poultry, and its microbial community plays an important role in nutrient utilization, immune stimulation, and pathogen exclusion (Oakley *et al.*, 2014). The litter ratio combinations in this study did not significantly influence the total bacterial counts in the caeca of broiler chickens. According to Stanley *et al.* (2014), the gut microbiota of poultry is influenced by several factors such as diet, environmental hygiene, and litter conditions, but differences in litter materials may not always result in significant microbial variations. Guardia *et al.* (2011) reported that litter management practices significantly influence the microbial environment of broilers and can modulate gut microbial populations even in the absence of significant caecal count differences.

Conclusion

Physicochemical properties of charcoal treated cassava peels as alternative litter compared favorably with wood shavings. The treatment groups with litter types alone or in ratio combinations had no detrimental effects on physiological traits, welfare parameters, carcass

characteristics and caecal bacteria counts of Arbor acres plus broiler chickens from day old to 6 weeks of age. It is therefore recommended that charcoal treated cassava peels can be used as alternative to conventional wood shavings litter in broiler chicken production without compromising their welfare or carcass quality.

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