Effect of different types of available litter materials on the performance and welfare of broiler chickens

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ABSTRACT:

This study was conducted to evaluate the quality of some locally available litter materials and their impacts on productivity, health status, carcass traits and welfare as well as the economic efficiency of broiler chickens reared on these types of litter. A total of 450 unsexed one-day-old *Cobb*^{500} broiler chicks were randomly distributed into equal five experimental groups, three replicates each. The groups of five different litter materials were as follow; wood shaving (WD), wheat straw (WS), sand (SL), bean straw (BS) and rice husk (RH). Physical and physicochemical characteristics of litter types were measured at 7, 21 and 42 days of age. Behavioral observation was carried out twice daily at two intervals. Productive and economic traits such as; LBW, BWG, ADG, FC, FCR, EPEI and economic efficiency per pen were measured or calculated. Further, some carcass traits and welfare parameters were measured at 42 day of age including footpad dermatitis (FPD) and feather condition score (FS). The results indicated that each type of litter had its unique physical and physicochemical characteristics and significantly (P≤0.05) affected most of the studied traits; productive performance (LBW, BWG, FI, FCR, livability %, and EPEI), economic feasibility, behavior patterns, and welfare. Compared different types of litter, WD and SL significantly (P≤0.05) improved growth performance, economic efficiency, behavior patterns, and birds' welfare. Interestingly, the SL group surpassed all other litter types groups in respect to productivity, behavior and welfare. Finally, it can be concluded that among the available litter materials tested, sand is advisable to be used as an alternative litter of straw and rice husk based litter for broiler chickens without adverse implications on birds' performance and welfare.

Keywords*:* broiler; behavior; litter type; performance; welfare.

INTRODUCTION

Undoubtedly, the deep litter system is the most popular system for housing broiler chickens and the birds generally spend their entire life in contact with this litter. Hence, choosing the appropriate type of litter becomes one of the most important managerial decisions. Furthermore, choosing alternatives to the common litter types used in poultry farms will be more challenging. In other words, litter is one of the most significant management practices influencing the performance of broiler chicken because they generally spend their entire life in contact with litter (Kryeziu et al., 2018 and McGahan et al., 2021). Also, litter quality plays an important role in leg and skin health conditions, respiratory infections and encouraging broiler behaviors and welfare (Farghly, 2017) where poor litter quality inversely affects the growth performance, health status, carcass quality, bird's welfare and project profits especially in broiler (Bilgili et al., 2009 and Farghly et al., 2021b).

Globally, the deep litter system is the most popular system for housing broiler chickens (Kryeziu et al., 2018 and McGahan et al., 2021). Moreover, in most countries such as Egypt, wood shaving and wheat straw are the commonest litter materials used in poultry farms. Availability of these substances will continue to decline as a result of rapid growth in broiler production, limited natural resources, competition with other industries, expanding lignocellulosic-based biofuel production, gradual ban of the cage system, use in animal feed, etc. (Ramadan et al., 2013; Kuleileet al., 2019; Moncktonet al., 2020 and Farghly et al., 2021a).

In Egypt and most countries of the world, there is an increasing need to explore and use unconventional litter materials alternatively to wheat straw and wood shaving. As a result of several factors, broiler producers and researchers are forced to look for alternative bedding materials for commercial poultry (Farghlyet al., 2015; Abougabal, 2019; Kuleile et al., 2019; and Monckton et al., 2020). During the past decade, several attempts have been made by using organic substances for bedding

such as wood sawdust, wheat straw, chopped rice straw, rice hulls, corn stalks, corn ear husks, sugarcane stalks, clover straw, chopped palm fiber, palm spines chips and other different types of grasses (Farghly, 2012; Karousa et al.,2012; Ramadan et al., 2013 and Farghly et al., 2021a,b). Moreover, several attempts used sand and vermiculite as an inorganic source for bedding (El-Sagheer et al., 2004; Balabel, 2005; Ramadan et al., 2013; Yildiz et al., 2014 and Ramadan & Khloya 2017) or reused shaving woods and wheat straw (El-Deek et al., 2011 and Abougabal, 2019).

Despite all these attempts under Egyptian conditions, many efforts for testing and utilizing more available bedding substances alternatively to wheat straw and wood by-products are needed. Although some types of litter have desired characteristics, they have not been used commercially in poultry industry due to economic cost, availability, industry need or lack in information about the litter quality and its impacts on the chicken performance, health status and birds' welfare (Bilgili et al., 2009 and Farghly et al., 2021b). Therefore, this study was conducted to evaluate some locally available and affordable litter materials (wood shaving (WD), wheat straw (WS), bean straw (BS), rice husks (RH), and sand (SL)) in terms of litter quality (physical and physicochemical properties) and their impact on the performance (productivity, health status, carcass traits and welfare, as well as the economic efficiency) of broiler chickens reared on these types of litter.

MATERIALS AND METHODS

Experimental design

All procedures performed in this study were conducted in compliance with the guidelines, ethical standards and recommendations of the Animal Ethical Committee of Al-Azhar University, Egypt.

The present experiment was performed at the Experimental Poultry Research Farm, Faculty of Agriculture, Al-Azhar University, Cairo, Egypt. For the present study, a total of 450 one-day-old unsexed broiler chicks (fast-growing *Cobb*^{500} strain) were purchased from a reputed commercial hatchery. Chicks were placed and brooded together in one compartment (3.5 x 4.2 m) of the house covered with new wood shaving as bedding litter during the first 7 days. After that, chicks were randomly distributed into five equal experimental groups with 3 replicates containing 30 mixed-sex chicks per pen (10 birds/m^2) for each treatment in a completely randomized design. The groups of five different litter materials were as follows; 1: Wood Shaving litter (WD), 2: Wheat Straw litter (WS), 3: Sand (medium-size-desert sand) Litter (SL), 4: Bean Straw litter (BS) and 5: Rice Husk litter (RH),respectively.

Birds' management

Except for litter type, all broiler chicks had a common environment. Birds were raised from 1 to 42 days of age during July and August (summer season) under similar environmental and managerial conditions in 15 floor pens (10 birds/m^2) with approximately 7 cm thickness of each experimental litter type. No litter was added, removed or replaced during the trial. All pens were identically equipped with round bell drinkers, plastic feeders, electric heaters and side curtains to control the house internal temperature. The birds were brooded at 33 °C that was gradually decreased weekly up to 28 °C by the end of 3rd week. The house temperatures during the rest period averaged (26.2±1.5 to 34.0±1.6 °C) with an average relative humidity that was 49.45 %. The lighting program was 24 h at 15 - 20 lux during the first week which was decreased to 22 h at 10 lux till the end of the experimental period. Birds were provided with feed and water *ad-libitum*. All diets were formulated to meet the nutritional requirements of strain guide recommendations. All chicks received a corn-soybean meal diet which was divided into three stages feeding program: a starter diet (1 - 11 d), a grower diet (12 - 24 d) and a finisher diet (25 - 42 d). Chicks were vaccinated against Newcastle disease (ND) and infectious bursal disease (IBD) by the farm veterinary authority and following all precautions recommended by the vaccine manufacturers.

Data collection and measurements:

Environmental data

Dry and wet bulb ambient temperatures were recorded daily at 1.00 pm inside the chicken house (from 3 different locations) using Psychomotor. Temperature degree °C and RH % were recorded daily through the experimental period. The temperature-humidity index was calculated according to the following equations:

$THI_{broilers} = 0.85\ T_{db} + 0.15\ T_{wb}$, (Tao & Xin, 2003).

Productive performance

All chicks in each replicate were weighed on an individual basis weekly from 1 to 6 weeks of age. Also, feed intake (FI) per replicate was recorded weekly. The estimated growth performance parameters as average live body weight (LBW), body weight gain (BWG), average daily gain (ADG), feed conversion ratio (FCR) and mortality rate were calculated for each pen. The economic efficiency of each treatment was calculated according to the actual prices prevailing in the Egyptian market during the experiment. The European production efficiency index (EPEI) was calculated according to the following formula:

$$EPEI = \frac{\text{Final body weight (kg)} \times \text{Livability (\%)}}{\text{Period (days)} \times \text{FCR}} \times 100$$

Slaughter test

At the end of the trial (42 days), two birds per replicate (1 male & 1 female) were randomly chosen (six birds/ treatment), fasted for 6 h, weighed and slaughtered and eviscerated. Carcass, liver, gizzard, heart, abdominal fat and lymphoid organs (spleen and bursa) were collected, weighed and calculated as a percentage of live body weight.

Welfare indicators and behavioral patterns

Regarding welfare indicators (footpad dermatitis and feather condition score), all birds were removed from their pens to determine footpad health and feather condition score by visual evaluation during harvesting. Footpad dermatitis (FPD) score was quantified visually for both legs separately using the four-point scale (from 0 to 3) as follows: 0) no lesions on the footpad; 1) Slight lesions (lesions cover less than 25% of the footpad); 2) Moderate lesions (lesions in wide areas covering between 25% to 50% of the footpad and 3) Severe lesions (more than 50 % lesion on the footpads) as described in details with photos (Eichner et al., 2007; Welfare Quality protocol, 2009 and RSPCA, 2013). At the same time, birds were subjected to feather condition (FS) score (plumage dirtiness) of the back, flank and breast. The score ranged from 0 to 3; 0) clean feather or not soiled; 1) slightly soiled; 2) moderate soiled and 3) heavily soiled as described in detail with photos (Welfare Quality protocol, 2009; RSPCA, 2013 and Farghly et al., 2018).

Behavioral pattern was evaluated for 3 consecutive days at the 3rd and 5th week of bird's age. Most common behaviors performed by broilers (eating, drinking, standing, walking, resting, dust bathing, preening, agonistic and flapping) were evaluated in the morning from 08:00 to 10:00 h. Instantaneous scanning observations method at the pen floor level were applied for 10 minutes intervals for each pen. Behaviors were recorded by 0:1 measurement (presence or absence) of each experimental unit. The percentage of birds engaged in each behavior was counted during all scan samples in each pen as clearly defined by Villagra et al., (2014) and Bergmann et al., (2017).

Physiological parameters

The measurements of physiological parameters (respiration rate and skin temperature) were conducted for 3 consecutive days at the 3rd and 5th week of bird's age. Within each treatment, 8 birds from each replicate (4 males & 4 females) were randomly chosen for measuring respiration rate and skin temperature. An infrared thermometer was used for measuring skin temperature. Respiration rate was measured by counting the movements of the body wall for one minute.

Litter quality

Physical and physicochemical properties of each litter type were evaluated at 7 (zero-time), 21 and 42 days of birds' age. Litter samples were collected from 5 different locations within each pen (4 corners and center). Each litter samples per pen were thoroughly mixed, bagged (200 g) and stored for subsequent analysis. Moisture content %, pH, bulk density and water holding capacity were determined using methods adopted by Brake et al., (1992) and AOAC (1995) guidelines. At the same time of samples collection, litter surface temperature was measured using an infrared

thermometer at five locations in each pen. Also, at the end of the trial (42 d), a scale from 0 to 4 was used to determine litter caking score per each pen for the caked litter surface area scored as follows: 0) No caking of litter; 1) caking in less than 1/4 of litter; 2) caking in 1/4 - 1/3 of litter; 3) caking in 1/3 - 1/2 of litter; and 4) caking in more than 1/2 of litter according to Welfare Quality Protocol (2009) and Farghly (2012).

Statistical analysis

All data were expressed as mean & SEM by one-way ANOVA with litter type as main factor using Statistical Package for Social Sciences (SPSS) software Ver. 24.0 (SPSS Inc., Chicago, IL, USA). Multiple comparisons among means were obtained when the factor had a significant effect using Duncan test method. A probability of $P \leq 0.05$ was required for statements of significance.

RESULTS AND DISSCUIONS

Productive performance parameters

The effects of different litter types on broiler performance are presented in tables 1 and 2. The results showed that litter type affected performance parameters of broiler chicks during the growing period. Significant differences in weakly LBW were observed between the different groups. Weakly LBW was significantly higher for broiler groups reared on WS and SL compared with groups reared on WS, BS and RH types. This trend was continued until the end of the growing period at the 6th week of age. Clearly, the results showed that the final LBW and BWG were significantly higher in groups of WD and SL by about 15 – 17 % compared to groups reared on WS, BS and RH bedding materials (table 2).

Furthermore, productive parameters (BWG, ADG, FI, FCR and EPEI) were significantly ($P \leq 0.05$) affected by litter type and took the same trend as found in LBW. Groups reared on WD and SL recorded the highest values of BWG, ADG and EPEI compared with other groups reared on WS, WS and RH litter types. In the same way, in connection with FCR, SL group scored the best values of FCR (1.73), followed by other groups raised on WD, RH, WS and BS (1.75, 1.79, 1.83 and 1.90, respectively). Regarding the mortality rate, broilers reared on SL type recorded the lowest mortality rate (2.15 %) followed by other groups raised on WS, WD, BS and RH (4.11, 4.37, 5.05 and 5.32 %, respectively) litter types. Finally and equally important, the results showed that broilers reared on SL and WD litter types recorded the highest values of EPEI compared to the other groups.

In the present study, the type of litter significantly influenced the performance parameters of broiler chicks during the growing period (tables 1 & 2). Regarding LBW and BWG, the results of the current study are in line with Toghyani et al., (2010) and Munir et al., (2019) who reported that the type of litter had a significant impact on LBW, BWG, FI and FCR of broiler chickens. Also, Farghly et al., (2021a,b) reported an improvement in different productive performance parameters of broilers, for example, up to 5 – 7 % improvement in FCR.

Based on productive performance, SL was the best potential type of litter for broiler chicks in terms of LBW, BWG and FCR. The improvement in growth traits (LBW, BWG, ADG and FCR) for broiler groups raised on SL and WS litters compared with other groups raised on WS, BS and RH litters could attribute to a significantly higher ingestive behavior which includes feeding and drinking which in turn reflected directly on the amount of FI and BWG of these birds. Also, another possible reason that birds raised on SL recorded better FPD scores (healthier) that make birds more able to walk for feeding and drinking. These results fully agreed with the finding of Bilgili et al., (1999) and El-Sagheer et al., (2004) who reported that birds reared on sand litter had significantly the heaviest body weights than those reared on wood by-products or wheat straw. Moreover, Ramadan et al., (2013) found that birds reared on wood shaving and sand showed significantly higher LBW and BWG than birds reared on straw at marketing age.

For the same reasons, the observed reduction in final LBW, BWG, RGR and FCR for broiler groups reared on WS, BS and RH litters may be due to increased leg disorders and feet lesions. Our results revealed that straw and rice husk litter material may be responsible for worse FCR in broiler chicks. This is in partial agreement with those of Atencio et al., (2010), Yildiz et al., (2014) and Monckton et al., (2020) who found that birds grow on wood-based litter were significantly heavier at the final week of age when compared with those raised on straw-based litters such as wheat and bean straw.

On the other hand, these results are in contrast with the findings of Bilgili et al., (2009), Karousa et al., (2012), Farghly (2012) and Farghly et al., (2015) who found

insignificant differences in growth parameters of broilers, quails and turkeys raised on different alternative litter materials. Moreover, litter material treatment had no significant influence on final BW and BWG (Kuleile et al., 2019) or on FI and FCR (Ramadan & Khloya, 2017). This conflict in results may be attributed to the differences in the broiler strains, stoking rates, housing conditions, seasonal variations and/or ration types.

Higher mortality percentage in BS and RH groups may be due to increased incidence of leg disorders and feet lesions for these groups that make birds unable to walk and die from starvation and dehydration or may be related to the high bacterial and mold content in straw-based litter or rice hulls. The differences in mortality percentage are consistent with Grimes et al., (2006) and Farghly (2012) who reported noticeable differences in mortality percentage of broilers and turkeys reared on different bedding materials. Also, El-Sagheer et al., (2004) found that birds reared on SL had fewer deaths than those on WS and WD litter type (16.7, 6.7 and 20.0 %, respectively). In contrast, Bilgili et al., (2009) and Farghly et al., (2012 & 2015) reported that mortality rates were not different among chickens raised on different litter materials. Also, Karousa et al., (2012) found no differences in mortality rates between groups reared on wheat straw, wood shavings and sugarcane bagasse (3.33, 3.05 and 2.77 %, respectively).

Carcass characteristics

Results presented in table 3 indicate that broiler reared on different litter types showed non-significant differences (P>0.05) for relative carcass traits (dressing, giblets, edible parts and abdominal fat) or immune organs (spleen and bursa) as a percentage of final LBW. However, the absolute weight (g) of the hot carcass was significantly higher in broiler birds raised on SL type followed by WD, BS, WS and RH litter type, respectively.

In the present study, the litter types did not affect relative carcass traits or immune organs (table 3). In line with our results, many authors indicated that relative carcass traits were not affected by the types of litter used for broilers (El-Sagheer et al., 2004; Toghyani et al., 2010; Farghly et al., 2015 & 2021a) or in turkeys (Farghaly, 2012). Moreover, El-Deek et al. (2011) found that the percentages of lymphoid glands were not significantly affected by litter types. Also, Ramadan & El-Khloya (2017) revealed that the percentage of LBW, heart, gizzard, spleen and bursa was not significantly different in birds reared on different types of litter. On the contrary, Toghyani et al., (2010) reported that only the broilers' gizzard percentage was significantly affected by litter type. This inconsistency in carcass traits may be due to the physical quality of litter such as particle size, moisture, caking score and other unknown substances that may affect the litter materials (Farghly, 2012).

Welfare indices and behavioral patterns

Footpad dermatitis and feather score

Table 4 shows that the type of litter significantly (P≤0.01) affected FPD and FS scores of broiler chickens. Regarding FPD score, birds reared on SL litter got the best scores of FPD (less dermatitis) followed by broilers reared on RH, WD, BS and WS litter types, respectively. Moreover, in connection with FS scores, group of FS behaved the same trend as found in FPD.

The broiler welfare assesses when the following parameters are considered; mortality or morbidity, body condition, behavior patterns and physiology parameters. Regarding Footpad dermatitis and feather score, the type of litter significantly affected FPD and FS scores of broiler chickens (table 4). These findings are compatible with those of El-Sagheer et al., (2004), Kuleile et al., (2019) and Farghly et al., (2015 & 2021 a,b) who reported that the type and quality of the litter had a significant effect on broiler welfare including scores of the footpad dermatitis and feather condition. In the present study, birds reared on sand showed lower FPD and better FS scores than broilers raised on straw-based litter (WS and BS) probably because of the differences in the quality of the litter types. Similar to our result, the birds raised on sand litter had healthier FPD than those raised on wheat and bean straw litters (Bilgili et al., 1999; Balabel, 2005 and Kuleile et al., 2019). Also, Ferrante et al., (2006) reported that feather scoring and footpad lesions were negatively affected by straw litter compared to wood shavings and sand.

Contrary to our results, no differences in footpad burns, hock discoloration and breast blisters in broilers or turkeys (Farghaly, 2012) reared on different types of litter materials. Moreover, Ramadan et al. (2013) indicated that litter type did not affect tonic immobility, plumage cover scores, footpad lesion, hock burns and leg health. They added that sand is possibly an alternative to wood shavings without negative impact on birds' welfare (Ramadan & El-Khloya, 2017). Also, Toghyani

et al., (2010) and Yildiz et al., (2014) declared the bedding type did not affect the plumage condition.

Behavioral patterns

Results of behavioral patterns of broiler chicks as affected by litter type at the 3rd and 5th week of age are presented in table (5). Litter types affect eating and drinking behaviors at the 3rd and 5th weeks. Also, litter types significantly affected patterns of dust bathing and preening behaviors at 3th week and walking, resting and pecking behaviors at 5th week. However, the type of litters had no significant (P>0.05) effect on behavioral patterns of resting, pecking, agonistic and flapping at 3rd week and dust bathing, preening, agonistic and flapping at 5th week.

Studying poultry behavior has introduced some evidence for understanding animals in order to improve living and housing conditions. Accordingly, behavior is a critical indicator of animal well-being. In the present study, the observed changes in some behaviors (table 5) agreed with previous work that reported that behaviors of broiler chicks were affected by different litter types (Shields et al., 2005; Balabel, 2005; Toghyani et al., 2010 and Ramadan et al., 2013). Using sand as litter significantly increased the patterns of ingestive behavior (including eating and drinking) and comfort behavior (including resting and dust bathing activities) compared to other types of litter. These results partially agreed with Toghyani et al., (2010) who stated that litter type significantly affected feeding and drinking behaviors. Contrarily, the type of litter had no significant effect on feeding and drinking behaviors in broiler chicks (Shields et al., 2005 and Ramadan & El-Khloya, 2017) or turkey (Farghaly, 2012).

Regarding the comfort behaviors (sitting, dust bathing and feather preening), birds reared on SL and WD were more comfort compared to those reared on the other types of litter. Broiler chicks seemed to prefer sand because finer materials are highly at penetrating the feathers to reach the downy plumage. In agreement with our results, Toghyani et al., (2010) found significant low locomotion behavior (walking and running) and higher sitting behavior on sand and wood shavings compared to rice hulls. Similarly, Ramadan et al., (2013) reported that birds preferred sitting and dust bathing behavior in sand and wood shavings rather than in straw-based litters and rice hulls (Balabel, 2005 and Shields et al., 2005). Contrarily, other studies showed that broilers' behavior did not differ between chickens reared on different types of litter (Farghaly, 2012 and Karousa et al., 2012).

Physiological parameters

The results presented in table 6 show that litter type has a significant effect (P<0.05) on physiological parameters (respiration rate and skin temperature) of broiler chicks at the 3rd week of age only. However, over the time, this significant effect on respiration rate and skin temperature was faded at finisher age (5th week of age). Moreover, it was remarkable that SL type reduced indoor THI that consequently reflected a significant reduction in thermoregulation responses (respiration rate and skin temperature) of broiler chicks raised on it during the early ages of the growing period.

The lower temperature of litter surface of SL type may be a contributing factor in improving house environment (indoor air temperature, RH % and THI index), which in turn decreased the birds' skin temperature and respiration rate as well as increased feeding pattern and feed intake and positively affected the final BW. The findings of our study are in full agreement with the findings of Gernat (2009) who declared that sand had the lowest temperatures that positively affected bird's body temperatures, particularly under summer season. Also, Kuleile et al., (2019) found that body temperature of the birds raised on wood shavings litter increased gradually while those reared on sand recorded lower body temperature than other studied litter materials.

Litter quality

The comparison of physical characteristics of different litter types is presented in table (7). Significant differences (P≤0.01) were observed in all physical characteristics (Ash, bulk density and WHC) among the different litter types. At zero time, SL type recorded higher percentage of ash content (95.20 %), higher bulk density (1.41 g/cm^3), lower moisture content (2.41 %) and lower WHC (0.18 g/g) compared to all other litter types. In contrast, WD litter recorded lower bulk density (0.07 g/cm^3) and the highest WHC (2.71 g/g) compared with the remaining litter types. Also, the litter quantity per unit of floor area (kg/m^2) was significantly different for each type of litter before use. Different litter sources and types have different characteristics especially bulk density, ash percentage and moisture content. These differences may be due the unique physical characteristics of each

litter, as reported earlier by Brake et al., (1992). These results are in line with the findings of Bilgili et al., (2009), Atencio et al., (2010), Karousa et al., (2012), Garcês et al., (2013), Ramadan et al., (2013) Farhadi (2014) and Farghaly et al., (2021a), who noticed significant differences in physical characteristics among different types of litter. Moreover, Ferrante et al., (2006) suggested that wood shavings had higher WHC and better litter quality than litter materials with poorer absorption capacity such as straw-based litters. On the other hand, the findings of Brake et al., (1992) and Kuleile et al., (2019) declared no significant difference in physical and chemical properties between wood shavings with wheat straw, rice straw and sand. Regarding bulk density and litter quantity per unit of floor area (kg/m^2), sand litter was heavier than WD by about 10 times which poses potential problems in handling and transportation. However, it is possible to overcome this problem by allowing broiler producers and farmers to raise several flocks on sand while removing only small portions of the wet litter on surface, which may compensate for these aspects and make it an appropriate litter source (Garcês et al., 2013).

The physicochemical characteristics of different litter types at different ages of the production period (7th, 21st and 42nd days of age) are presented in table 7. Highly significant differences (P≤0.01) were observed in all physicochemical characteristics (litter surface temperature °C, moisture percentage, pH values and caking score) among all types of litter. Regarding litter temperature, SL type was significantly lower at zero-day (7th day of age) than BS, RH and WS litter types, respectively. With the time, at 21st and 42nd days of age, litter temperature degree increased in all types of litter but the differences became insignificant at 42nd. In the same context, high significant (P≤0.01) differences were found between different types of litter for moisture and pH among all types of litter. Rice hull litter was more acidic than other litter types on day 7. But after that, there was a trend of increasing pH from 7th to 42nd days in all litter types due to fecal accumulation. Interestingly, SL type recorded a lower pH value especially at 42nd days of broiler age, compared to other litter types. Regarding litter caking score, it was significantly (P≤0.05) at 42nd day of broiler age. Sand litter type recorded better caking score (lower score %) followed in ascending order by RH, WD, WS and BS litter types, respectively.

Regarding litter temperature, these results fully agreed with Atencio et al., (2010) who reported that litter surface temperatures were significantly higher for WS, RH and BS compared to sand. The lower temperature of litter surface found under SL could contribute to improving house environment, which was positively affected the final body weight (Kuleile et al., 2019). In the same context, each type of litter has different moisture content that may be due to its unique characteristics (Brake et al., 1992). The average moisture percentage for all litter types increased almost 2 - 3 times throughout the rearing period. But higher moisture was observed in WS litter type (30.88 %) followed in descending order by WD, BS, RH and SL types (25.73, 28.20, 18.98 and 12.95 %, respectively) at the 42nd day. This gradual increase in the moisture content in all litter types was based on increased waste accumulation, water spillage, birds' respiratory evaporation in growing birds as well as air humidity (Brake et al., 1992 and Garcês et al., 2013).

Furthermore, the increase in litter moisture may be due to the reduction in the ability to adsorb moisture for straw-based litter and rice husk (Toghyani et al., 2010 and Farghaly et al., 2021a). In our study, sand type had lower moisture content compared to other types. Therefore, birds reared on it showed good welfare signs and improved behavior. Similar results were obtained in the previous studies (Balabel 2005; Karousa et al., 2012 and Ramadan et al., 2013). Also, Atencio et al., (2010) found that sand maintained approximately 15 % lower moisture levels in comparison to pine wood shavings and rice hulls.

Regarding litter caking score, caked and wet litter is typically having a considerable negative impact on performance, welfare and overall profitability. Ideally, litter should be managed to have less than 25% moisture. Atencio et al., (2010) found that sand maintained approximately 15% lower moisture levels compared to pine wood shavings and rice hulls. The present study indicated that wheat and bean straw litters are vulnerable for easier caking than wood shaving and sand. The moisture content and other physical appearance of the material affect the degree of litter cake formation, footpad dermatitis and plumage cleanness. Furthermore, the success of using WD, WS, SL, BS and RH as bedding materials depends on their ability to absorb the moisture (Grimes et al., 2006 and Farghly, 2012). Similar results were obtained by Balabel

(2005),Toghyani et al., (2010), El-Deek et al., (2011), Farghaly (2012),Garcês et al., (2013) and Kuleile et al., (2019) who reported that litter pH, moisture %, nitrogen %, bacterial count and caking rate were significantly affected by a different type of litter. Contrarily, Grimes et al., (2006) found no differences in incidence of litter caking and condition by litter types.

Economic considerations

Data presented in table 8 show that all economic considerations parameters (inputs and outputs items) of broiler groups were significantly (P≤0.05) affected by the type of litter. In this context, as expected, using sand as a litter for broiler production requires a large quantity of litter material (kg/m^2). But, the SL type was cheaper per bird than other bedding materials used in this study, which positively was reflected in reducing the variable costs (litter cost per bird) and total cost of broiler production.

Furthermore, broiler chicks reared in WD and SL litter type recorded higher LBW and livability %, which positively affected the total and net revenue of broiler production compared to other litter types. Total and net revenue were significantly higher for the broiler group raised on SL followed in descending order by WD, WS, RH and BS groups, respectively. In the same way, the economic efficiency of broiler production in this study was significantly higher for the SL group (0.33) followed by other groups raised on WD, WS, RH and BS (0.29, 0.21, 0.19 and 0.16 %), respectively.

In the present study, the litter type affected broiler profitability (table 8). Clearly, birds raised on sand litter had the best economic efficiency value compared with groups raised on other types of litter. Similarly, Farghly (2017) reported that litter type had significant effect on economic efficiency. These results fully agree with El-Sagheer et al., (2004), who found that sand litter birds had the best E.E value compared with groups raised on wood shaving and wheat straw. Also, Abdel-Hafeez et al., (2009) reported that sand litter type is better than sawdust regarding availability and economics.

CONCLUSION AND RECOMMENDATION

It can be concluded that each type of litter had its unique physical and physicochemical characteristics, affecting growth performance, welfare and behavior pattern as well as economic efficiency of broiler chickens. Among the available litter material tested in this study, sand could be used as a litter for broiler without adverse implications on performance and welfare compared with straw- and rice husk-based litter. The results of the current study recommended using sand as a good alternative litter material. The imposed challenges by its bulk density might be overcome by reusing the same litter for several flocks before cleaning the broiler house. Further studies that include measuring the impact of litter type on immunoglobulin concentration, antioxidant capacity as well as the bacterial count could be useful and necessary.

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Table 1: Live body weight (g) of broiler chicks reared on different litter types.

Age (week)	*Types of Litter**					*S.E.M*	*P. Value*
	WD	WS	SL	BS	RH		
1st Wk	181.84	182.25	181.01	181.23	181.33	1.350	0.989
2nd Wk	497.74^{a}	479.50^{bc}	485.45^{ab}	469.31^{bc}	465.33^{c}	2.850	0.002
3rd Wk	944.19^{a}	869.06^{b}	944.33^{a}	876.50^{b}	888.83^{b}	6.750	0.000
4th Wk	1400.16^{a}	1286.21^{b}	1392.67^{a}	1267.76^{b}	1273.83^{b}	9.980	0.000
5th Wk	1975.67^{a}	1752.19^{b}	1935.33^{a}	1731.90^{b}	1709.43^{b}	19.030	0.000
6th Wk	2528.93^{a}	2126.90^{b}	2469.07^{a}	2130.56^{b}	2115.93^{b}	25.990	0.000

Means bearing different superscripts within a raw are different ($P \leq 0.05$).

*WD: wood shaving, WS: wheat straw, SL: sand, BS: bean straw and RH: rice husk.

Table 2: Productive performance of broiler chicks reared on different litter types.

Traits	*Types of Litter**					*S.E.M*	*P. Value*
	WD	WS	SL	BS	RH		
Body Weight gain (g)	2347.32^{a}	1945.69^{b}	2290.07^{a}	1949.85^{b}	1934.70^{b}	25.99	0.000
Average Daily Gain	67.07^{a}	55.59^{b}	65.43^{a}	55.71^{b}	55.28^{b}	0.743	0.000
Final LBW (kg)	2.53^{a}	2.12^{b}	2.47^{a}	2.13^{b}	2.11^{b}	0.060	0.001
Total FI (Kg)	4.11^{a}	3.56^{c}	3.98^{ab}	3.70^{bc}	3.47^{c}	0.080	0.014
FCR	1.75^{c}	1.83^{b}	1.73^{c}	1.90^{a}	1.79^{b}	0.020	0.000
Mortality rate %	4.37	4.11	2.15	5.05	5.32	0.490	0.288
Livability %	95.63	95.89	97.85	94.95	94.68	0.490	0.287
EPEI	328.49^{a}	265.07^{b}	332.67^{a}	252.42^{b}	265.65^{b}	9.780	0.000

Means bearing different superscripts within a raw are different ($P \leq 0.05$).

*WD: wood shaving, WS: wheat straw, SL: sand, BS: bean straw and RH: rice husk.

Table 3: Carcass characteristics of broiler chicks reared on different litter types.

Traits	*Types of Litter**					*S.E.M*	*P. Value*
	WD	WS	SL	BS	RH		
LBW (g)	2458.00^{a}	2132.00^{b}	2482.00^{a}	2146.00^{b}	2148.00^{b}	30.480	0.000
Carcass (g)	1858.93^{a}	1631.63^{b}	1861.22^{a}	1645.20^{b}	1619.15^{b}	21.580	0.000
Carcass yield (%)	75.62	76.53	74.98	76.65	75.40	0.230	0.088
Giblets (%)	3.62	3.74	3.81	3.51	3.57	0.041	0.120
Edible parts (%)	79.28	80.3	78.98	80.28	79.3	0.210	0.122
Abdominal fat (%)	0.98	1.09	1.04	0.78	0.86	0.077	0.071
Spleen (%)	0.11	0.11	0.13	0.10	0.11	0.013	0.074
Bursa (%)	0.11	0.13	0.11	0.12	0.12	0.016	0.065

Means bearing different superscripts within a raw are different ($P \leq 0.05$).

*WD: wood shaving, WS: wheat straw, SL: sand, BS: bean straw and RH: rice husk.

Table 4: Footpad and feather condition scores of broiler chicks reared on different litter types.

Traits	*Types of Litter**					*S.E.M*	*P. Value*
	WD	WS	SL	BS	RH		
			Footpad score (%)				
FP 0	79.33^{c}	33.70^{e}	94.99^{a}	44.52^{d}	82.85^{b}	6.350	0.000
FP 1	11.20^{c}	42.10^{a}	5.01^{d}	23.60^{b}	11.43^{c}	3.530	0.000
FP 2	9.47^{c}	19.99^{b}	0.00^{e}	23.60^{a}	5.72^{d}	2.360	0.000
FP 3	0.00^{c}	4.21^{b}	0.00^{c}	8.28^{a}	0.00^{c}	0.920	0.000
			Feather Score (%)				
FS 0	20.43^{b}	16.75^{c}	26.46^{a}	11.75^{d}	23.24^{a}	0.990	0.000
FS 1	43.65^{b}	40.36^{b}	48.93^{a}	29.83^{c}	41.59^{b}	1.500	0.000
FS 2	27.45^{b}	32.31^{a}	18.60^{c}	33.73^{a}	23.90^{c}	1.020	0.000
FS 3	8.47^{bc}	10.59^{b}	6.01^{c}	24.69^{a}	11.28^{b}	1.570	0.000

Means bearing different superscripts within a raw are different (P ≤ 0.05).

*WD: wood shaving, WS: wheat straw, SL: sand, BS: bean straw and RH: rice husk.

Table 5: Behavioral patterns of broiler chicks reared on different litter types.

Traits	*Types of Litter**					*S.E.M*	*P. Value*
	T1: WD	T2: WS	T3: SL	T4: BS	T5: RH		
			Behavioral (%) of broiler at 20th days				
Eating	23.84^{ab}	19.80^{b}	25.00^{a}	14.59^{c}	17.71^{b}	0.840	0.031
Drinking	11.46^{a}	8.34^{ab}	5.21^{b}	7.29^{b}	6.25^{b}	0.740	0.040
Walking	7.29	7.29	3.13	5.21	8.34	1.010	0.552
Resting	61.04	57.29	63.55	43.55	55.63	3.150	0.636
Pecking	7.29	5.21	6.08	1.04	6.25	1.000	0.213
Dust bathing	12.50^{a}	7.17^{c}	10.21^{b}	4.17^{c}	12.50^{ab}	0.610	0.045
Preening	13.54^{a}	9.54^{ab}	12.21^{a}	7.34^{c}	9.38^{ab}	0.750	0.047
Agonistic	0.00	5.21	2.08	0.00	0.00	0.800	0.145
Flapping	0.00	5.21	4.17	0.00	0.00	1.000	0.261
			Behavioral (%) of broiler at 35th days				
Eating	20.84^{ab}	15.63^{c}	21.88^{a}	16.67^{c}	18.84^{b}	0.860	0.033
Drinking	8.34	8.34	10.42	8.34	11.46	0.680	0.496
Walking	8.34^{a}	2.09^{b}	5.21^{ab}	2.09^{b}	6.25^{ab}	0.910	0.099
Resting	78.13^{ab}	71.88^{ab}	82.30^{a}	67.71^{b}	76.04^{ab}	1.990	0.153
Pecking	2.09^{ab}	2.09^{ab}	1.04^{b}	5.21^{a}	1.04^{b}	0.570	0.093
Dust bathing	2.09	1.04	3.13	1.04	0.00	0.520	0.415
Preening	2.08	1.04	3.13	0.00	0.00	0.730	0.667
Agonistic	1.04	1.04	0.00	0.00	0.00	0.280	0.580
Flapping	2.09	1.04	0.00	0.00	0.00	0.330	0.171

Means bearing different superscripts within a raw are different (P ≤ 0.05).

*WD: wood shaving, WS: wheat straw, SL: sand, BS: bean straw and RH: rice husk.

Table 6: Physiological parameters of broiler chicks reared on different litter types.

Traits		*Types of Litter**					*S.E.M*	*P. Value*
		WD	WS	SL	BS	RH		
Indoor Air Temp. (˚C)	3th W	29.64	30.10	29.07	31.08	30.81	0.200	0.077
	5th W	31.95	29.88	28.97	30.87	30.98	0.620	0.643
Indoor Relative Humidity (%)	3th W	49.44	51.38	48.15	52.38	49.00	1.440	0.059
	5th W	53.21	57.81	52.01	54.44	55.50	1.780	0.127
Indoor THI	3th W	77.51	78.59	75.54	78.97	77.51	0.430	0.140
	5th W	76.13	79.32	76.92	77.15	78.45	0.630	0.350
R.R (R./min.)	3th W	66.33^{ab}	65.00^{bc}	58.50^{c}	74.00^{a}	69.33^{ab}	1.410	0.004
	5th W	57.00	53.00	58.50	56.67	53.67	0.890	0.245
Skin Temp. (˚C)	3th W	40.15^{b}	40.87^{a}	39.85^{b}	40.95^{a}	40.40^{ab}	0.110	0.01
	5th W	40.25	40.27	40.02	40.77	40.57	0.100	0.128

Means bearing different superscripts within a raw are different (P ≤ 0.05).

*WD: wood shaving, WS: wheat straw, SL: sand, BS: bean straw and RH: rice husk.

Table 7: Litter quality of the experimental litter materials.

Traits		*Types of Litter**					*S.E.M*	*P. Value*
	Age	WD	WS	SL	BS	RH		
				Physical characteristics				
Initial Moisture %	-	8.58^{c}	7.94^{d}	2.41^{e}	9.74^{b}	10.31^{a}	0.670	0.000
Initial pH	-	6.73^{b}	6.67^{b}	7.28^{a}	6.70^{b}	6.41^{c}	0.062	0.000
Ash (%)	-	11.06^{b}	8.79^{c}	95.2^{a}	9.57^{c}	5.94^{d}	7.936	0.000
Bulk Density (g/cm^3)	-	0.07^{c}	0.07^{c}	1.41^{a}	0.08^{c}	0.12^{b}	0.122	0.000
WHC (g/H_2O g)	-	2.71^{a}	2.45^{b}	0.18^{d}	2.52^{b}	1.88^{c}	0.213	0.000
				Physicochemical properties				
Litter Temperature (˚C)	0	28.90^{c}	28.62^{c}	28.02^{c}	30.15^{a}	29.08^{b}	0.114	0.000
	21	29.05^{b}	31.01^{ab}	28.52^{c}	31.05^{ab}	31.50^{a}	0.269	0.015
	42	30.22	31.88	30.08	31.25	31.15	0.190	0.102
Moisture (%)	0	8.58^{c}	7.94^{d}	2.41^{e}	9.74^{b}	10.31^{a}	0.670	0.000
	21	18.89^{b}	21.78^{a}	8.64^{d}	18.55^{b}	13.64^{c}	1.155	0.000
	42	25.73^{b}	30.88^{a}	12.95^{d}	28.20^{ab}	18.98^{c}	1.377	0.000
pH	0	6.73^{b}	6.67^{b}	7.28^{a}	6.70^{b}	6.41^{c}	0.062	0.000
	21	7.96^{a}	7.39^{bc}	7.59^{b}	7.27^{c}	7.10^{d}	0.078	0.000
	42	8.38^{a}	8.09^{ab}	7.85^{bc}	7.87^{bc}	7.98^{c}	0.072	0.000
Caking Score	0	0.00	0.00	0.00	0.00	0.00	---	----
	21	0.75	1.00	0.35	1.25	0.50	0.131	0.142
	42	1.75^{b}	2.50^{a}	1.05^{d}	2.75^{a}	1.50^{c}	0.185	0.006

Means bearing different superscripts within a raw are different (P ≤ 0.05).

*WD: wood shaving, WS: wheat straw, SL: sand, BS: bean straw and RH: rice husk.

Table 8: Economical efficiency of broiler chicks reared on different litter types.

Traits	*Types of Litter**					*S.E.M*	*P. Value*
	WD	WS	SL	BS	RH		
Litter Cost/bird*[1]	0.02[d]	0.03[c]	0.01[c]	0.04[b]	0.05[a]	0.004	0.000
LBW (kg)	2.53[a]	2.12[b]	2.47[a]	2.13[b]	2.11[b]	0.06	0.001
FI (kg)	4.11[a]	3.56[c]	3.98[ab]	3.70[bc]	3.47[c]	0.08	0.014
Feed Cost	1.93[a]	1.67[c]	1.86[ab]	1.74[bc]	1.62[c]	0.04	0.013
Total Cost[2]	2.58[a]	2.32[c]	2.50[ab]	2.40[bc]	2.30[c]	0.04	0.023
Total Revenue[3]	3.33[a]	2.80[b]	3.33[a]	2.77[b]	2.75[b]	0.08	0.001
Net Revenue[4]	0.75[a]	0.48[b]	0.83[a]	0.38[b]	0.45[b]	0.05	0.000
E. efficiency[5] (%)	0.29[a]	0.21[b]	0.33[a]	0.16[b]	0.19[b]	0.02	0.000

* Exchange rate: 16 L.E = 1 US $

[1]Litter cost/bird in US dollar = (Price of Kg litter * Litter quantity/M2) / Density

Prices: Chick = 0.38 $/chick, Medical and management = 0.38 $/bird, Feed = 0.41 $/kg, Live meat = 1.38 $/kg.

[2]Total cost = Feed + check + management + litter, [3]Total Revenue = LBW * Livability % * 1.38 $,

[4]Net Revenue = Total Revenue – Total cost & [5]Economic efficiency = Net Revenue / Total cost

Means bearing different superscripts within a raw are different (P ≤ 0.05).

*WD: wood shaving, WS: wheat straw, SL: sand, BS: bean straw and RH: rice husk.

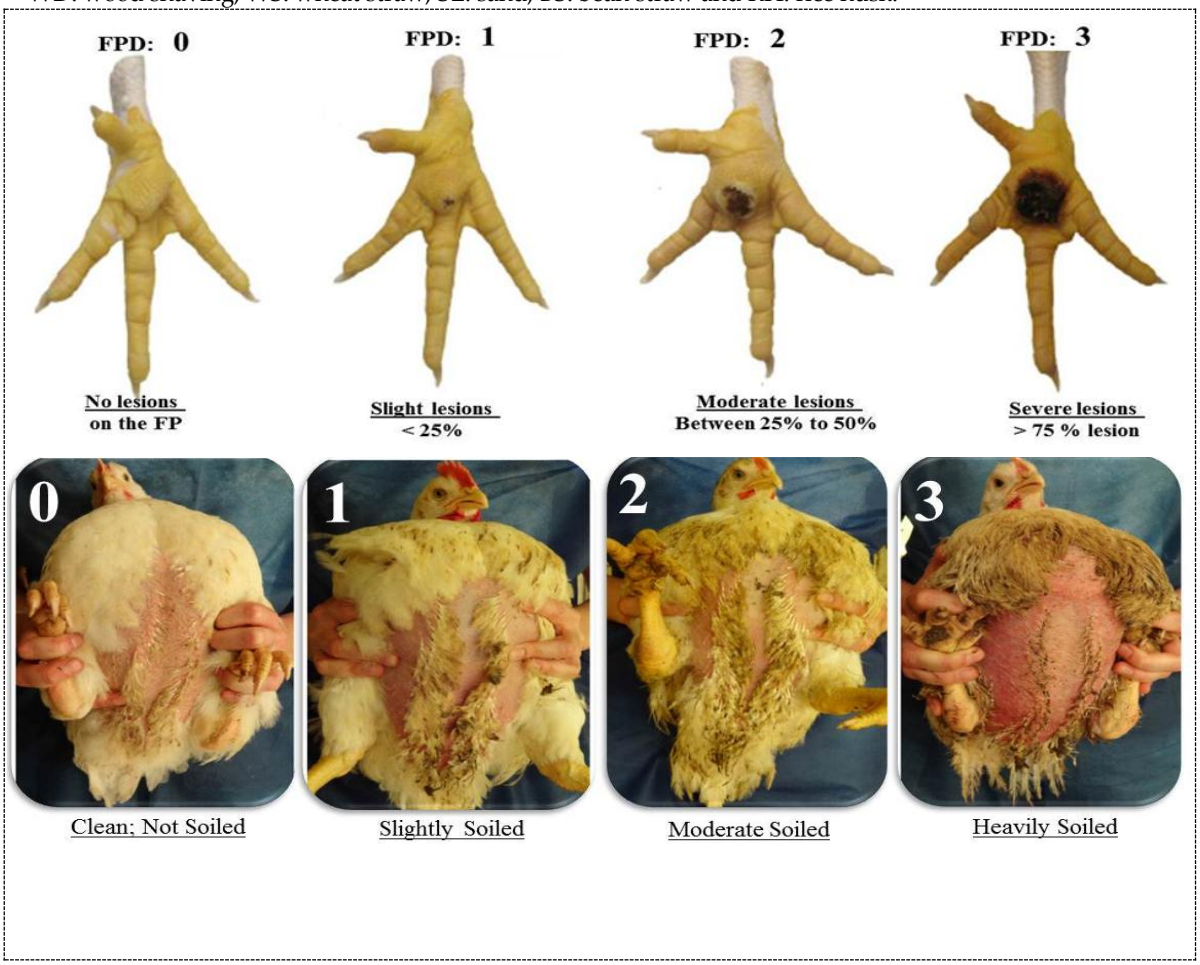

Figure 1: Descreption of scoring sytem applied to evaluated footpad dermatitis (Top fig.) and feather condition (bottom fig.). The images were collected and edited from Welfare Quality protocol (2009) and RSPCA (2013).

تأثير الأنواع المختلفة لمواد الفرشـة المتاحة على أداء ورفاهية دجـــاج التسمين

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الملخص العربي

أجريت هذه الدراسة لتقييم جودة بعض أنواع الفرشة المتوفرة محليًا وتأثيرها على الإنتاجية والحالة الصحية وصفات الذبيحة ورفاهية كتاكيت دجاج التسمين المربى على هذه الأنواع من الفرشة بالإضافة إلى الجدوى الإقتصادية. ولهذا الغرض إستخدم 450 كتكوت تسمين غير مجنسين (كوب ^{500}) وعند عمر 7 أيام تم تقسيمها وتوزيعها عشوائيا إلى خمس مجموعات تجريبية متساوية (5 مجموعات * 3 مكررات * 30 طائر) وكانت مجموعات الطيور حسب نوعية الفرشة المرباة عليها كالتالى: نشارة الخشب (WD) ، تبن القمح (WS) ، الرمل (SL) ، تبن الفول البلدى (BS) وسرس الأرز (RH). تم قياس الخصائص الفيزيائية والكيميائية لأنواع الفرشة المستخدمة عند أعمار الطيور 7 و 21 و 42 يومًا. تم تسجيل القياسات الفسيولوجية (التنظيم الحرارى) والأنماط السلوكية للطيور خلال فترتين أثناء التجربة. وأيضا تم قياس الصفات الإنتاجية وحساب الجدوى الاقتصادية لكل مجموعة من الطيور. وعلاوة على ذلك تم تقدير بعض صفات الذبيحة ومؤشرات الرفاهية (التهابات باطن القدم ونظافة الريش) عند 42 يومًا من العمر. أظهرت النتائج إلى أن لكل نوع من الفرشة خصائصه الفيزيائية والكيميائية المميزة له والتى تتفرد به عن غيرها من الأنواع والتى بدورها أثرت نوعية الفرشة بصورة معنويًا ($P\leq0.05$) على معظم الصفات التي تمت دراستها مثل قياسات الأداء الإنتاجي (LBW و BWG و FI و FCR و Livability وكذلك EPEI) وأيضا الجدوى الإقتصادية وأنماط السلوك و رفاهية الطيور عدا ذلك فإن صفات الذبيحة فقط لم تكن الفروق معنوية. وعند المقارنة بين الأنواع المختلفة من الفرشة لوحظ أن إستخدام نشارة الخسب (WD) والرمل (SL) كفرشة للطيور حسّن قياسات النمو بشكل ملحوظ (BWG و ADG و LBW النهائي و FI و FCR وكذلك EPEI). علاوة على ذلك حسّن إستخدام فرشة نشارة الخشب والرمل الجدوى الإقتصادية وأنماط السلوك ورفاهية الطيور المرباة لكلا من المجموعتين. لكن النتيجة الأفضل والمثيرة للإهتمام هى أن مجموعة الطيور المرباة على فرشة من الرمـل (SL) تفوقت على جميع المجموعات المرباة على الأنواع الأخرى من الفرشة. وختاما تلخص وتوصى نتائج هذه الدراسة أنه من بين مواد الفرشة المتاحة محليا والتي تم اختبارها يمكن إستخدام الرمل كفرشة للأرضية بديلا عن أنواع الفرشة المعتمدة على الخشب والتبن والقش وسرس الأرز لكتاكيت دجاج التسمين دون أى آثار سلبية على أداء الطـيور من الناحية الإنتاجـية والسلوكـية والرفـاهية وكذلك الإقتصادية.

الكلمات الاسترشادية: الدجاج، السلوك، انواع الفرشة، الاداء, الرفاهية.