JAST (Journal of Animal Science and Technology) TITLE PAGE

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ARTICLE INFORMATION	Fill in information in each box below
Article Type	Short Communication
Article Title	Differences in bedding material could alter the growth performance of White Pekin ducks raised for 42 days
Running Title	Bedding materials and physiological responses of ducks
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Competing interests	No potential conflict of interest relevant to this article were reported.
Funding sources State funding sources (grants, funding sources, equipment, and supplies). Include name and number of grant if available.	This paper was financially supported by the research fund of the Ministry of Agriculture, Feed and Rural Affairs (321092-03-2-HD020).
Acknowledgments	The authors greatly appreciate the financial and material support provided by the Ministry of Agriculture, Feed and Rural Affairs.
Availability of data and material	Upon reasonable request, the datasets of this study can be available from the corresponding author.
Authors' contributions Please specify the authors' role using this form.	Conceptualization: Yu Bin Kim, Myunghwan Yu, Jung Min Heo. Data curation: Yu Bin Kim, Jung Min Heo. Formal analysis: Shan Randima Nawarathne, Jung Min Heo. Methodology: Yu Bin Kim, Elijah Ogola Oketch. Software: Jun Seon Hong, Yu Bin Kim. Validation: Jung Min Heo. Investigation: Elijah Ogola Oketch, Yu Bin Kim. Writing - original draft: Elijah Ogola Oketch, Jung Min Heo Writing - review & editing: Elijah Ogola Oketch, Yu Bin Kim, Myunghwan Yu, Jun Seon Hong, Shan Randima Nawarathne, Jung Min Heo.
Ethics approval and consent to participate	The experimental protocol and procedures for the current study were reviewed and approved by the Animal Ethics Committee of Chungnam National University (Protocol Number; 202109A-CNU-111).

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Abstract

The effect of different commercially available bedding materials on the growth performance and carcass characteristics of ducks for 42 days was investigated. 336 one-day-old White-Pekin ducklings (60.48 ± 0.16 g) were randomly allocated into 24-floor pens with one of the three beddings namely i) coco peat, ii) rice husks, or iii) sawdust. 14 ducklings per pen and 8 replicate pens per bedding material were used. Birds were fed a starter diet from day 1-21 and a grower diet from day 22-42. Weekly growth performance evaluation was conducted for the average body weight, weight gains, daily feed intake, and feed conversion efficiency. One bird per pen was sacrificed on d 42 for the evaluation of carcass characteristics including the carcass, breast, and leg muscle percentages. Breast and leg muscle samples were then collected and analyzed for their proximate and pH values. Higher body weights ($p< 0.05$) were noticed with rice husks on day 42 only. Improved daily gains ($p < 0.05$) were also noticed for birds raised with rice husks over the entire period (days 1-42). Concerning feed intake, higher values ($p < 0.05$) were similarly noted with rice husks for the grower phase (day 22-42), and the entire experimental period (d1-42). Marginally improved feed intake values were also noted with the use of rice husks as the bedding materials on d 42 ($p = 0.092$). Improved feed efficiency ($p < 0.05$) was noticed with rice husks on d 35, the grower period, and the entire 42-day period. However, no significant differences were noticed for most of the carcass characteristics that were evaluated. Nevertheless, higher ($p < 0.05$) pH values for the breast muscle were noticed with the use of coco peat and sawdust as the bedding. Conclusively, the bedding type could have a significant impact on the growth performance of ducks without adverse effects on carcass characteristics. The use of rice husks as bedding might be advantageous and is therefore recommended.

Keywords: Bedding, carcass, coco peat, growth performance, rice husks, sawdust

Introduction

As a sub-sector of the larger growing poultry industry, the duck husbandry has undergone tremendous progress, especially in Asia [1, 2]. This change could be attributed to nutritional and genetic progress and to a better understanding of the management-oriented aspects such as housing and its accompanying factors, such as floor type, ventilation, and temperature control [3-5]. Despite being waterfowls like geese, ducks are reared mainly in intensive production systems that are characterized by indoor housing. As the preference for duck meat and eggs increases, the shift towards intensification allows for better environmental control and higher stocking densities [6].

Indoor housing necessitates the provision of bedding materials under deep-litter floor systems with potential impacts on productive indices, including growth performance, meat quality, and the health, well-being, and welfare of birds [7-9]. Bedding material cushions the birds from the cooling effects of the floors (mostly concrete), absorbs excess moisture from faecal droppings and drinkers, dilutes faecal compounds, and subsequently reduces the exposure of birds to manure by keeping the top layer of the bedding material dry [10,11]. Notably, bedding has been constantly referred to as litter as it is a mixture of bedding material, wasted feed, faecal matter, and feathers [12]. An effort has been made to ensure the accurate application of these two terms in this paper.

Several materials can be used for bedding, including pine shavings, wheat straw, wood sawdust, peanut shells, rice husks, sand, wood shavings, shredded and processed paper, corn stalks, coco peat, dried leaves, and peat moss [13-15]. During optimization of production systems, the bedding material could be decided largely based on availability

and cost. Several factors should be considered when determining the suitability as ideal bedding materials. This includes low moisture content (MC), high water adsorbing/holding capacity, quick drying capacity, low thermal conductivity, and acceptability as fertilizer material [16,17].

Nevertheless, in addition to focusing on providing bedding materials, routine management must be performed to ensure bedding quality. Poor quality bedding, which can be characterized by abrasiveness, sharpness, caking, and wetness (above 25% MC), could lead to gait problems, higher ammonia emissions, the proliferation of pathogens, and increased incidences of footpad and hock dermatitis with detrimental impacts on welfare, growth performance, and carcass quality [18-20]. Different bedding materials could have varied responses in poultry production as has been previously reported [16, 21, 22].

It was hypothesised that ducks raised on different bedding materials could exhibit variable responses even when stocked at the same rate and raised in the same indoor housing unit. Therefore, the current experiment was conducted to determine the effect of different commercially available bedding materials, including i) coco peat, ii) rice husks, and iii) sawdust, on indices of growth performance, including mortality, body weight, daily weight gain, feed intake, and conversion efficiency. Additionally, the potential effects of dissimilar bedding materials on carcass characteristics such as the carcass, leg, and breast percentages, muscle pH, and proximate composition of ducks were analyzed for 42 days.

Materials and Methods

The experimental protocol and procedures were reviewed and approved by the Animal Ethics Committee of Chungnam National University (Protocol Number; 202109A-CNU-111). The experiment was conducted at the Cheongyang Animal Research Unit for Chungnam National University.

Birds, diets, and housing

A total of 336 White Pekin ducklings (60.48 ± 0.16 g) were raised for 42 days under the same feeding and environmental conditions except for the different bedding materials that were being investigated. The birds were weighed on arrival and randomly allocated to 24-floor pens (8 replicate pens per treatment). 14 birds were used per pen (1.7 m × 1.3 m × 1.0 m) and raised with one of the three bedding materials. Each pen was fitted with six nipple drinkers and a feed trough for the efficient provision of water and feed, respectively. Birds were allowed free access to fresh drinking water and feed throughout the entire experimental period. Regularly, the environmental conditions were monitored and adjusted according to the birds' behavior and age. The birds were fed over two phases with standard starter (days 1-21, 22% CP) and grower diets (days 22-42, 17.5% CP), that were pellet in form.

Bedding Materials

Three bedding materials including cocopeat, rice husks, and sawdust were evaluated in the current study for their effect on growth performance and some carcass characteristics. All the bedding materials were supplied at a depth of approximately 8-10 cm which was presumed to be deep enough to avoid the need for a constant replacement that could be noticed by thinner bedding [23] but also not too thick to avoid potential wastages.

Cocopeat is a reddish-brown colored spongy biowaste from the processing of coir fibers from coconut husks [24]. Consisting primarily of lignin and cellulose, cocopeat is known to readily absorb water and dust due to the presence

of hydroxyl, carboxyl, ether, phosphate, and amino groups [25]. Alongside being lightweight, and thus easy to handle, coco peat is also known to be pathogen-free, highly renewable with a slow decay rate, and a slightly acidic pH of around 5.5-6.5 which could be vital in the prevention of microbial proliferation [24, 26]. Aimed at utilizing its great absorptive qualities, it has been widely used for agronomic purposes as well as other roles [25, 27].

Rice husks are the hard protective coverings derived from the milling process of rice grains. As outlined by Casas [28], rice husks constitute about 20% of the weight of the rice grain, with high cellulose, lignin, arabinoxylans, and ash percentages (25, 30, 15, and 21, respectively). The ash is composed mainly of silica (over 85%) and could be used for a wide variety of industrial applications [29]. Rice husks could also be used for poultry feeding [30]. Wood shavings are small wood chippings that could result from woodworking processes such as sawing, milling, planning, and sanding. It has been widely used as a common bedding material for poultry production [31] even though it could pose respiratory problems to ducks due to dust [6].

Growth performance evaluation

Weekly assessments for the growth performance were done using individual bodyweight measurements and feed consumed data that was recorded on days 7, 14, 21, 28,35, and 42. Further measurements were conducted for the evaluation of the growth performance within the starter (d 1-21) and the grower period (d 22-42). Using the feed consumed and recorded body weights, the average daily gain (ADG), mortality-corrected average daily feed intake (ADFI), and the feed conversion ratio (FCR) to depict the efficiency of converting feed supplied to lean muscle was conducted.

Carcass evaluation

Carcass evaluation was done on day 42 after a 12-hour fasting period. One duck was selected based on closeness to the mean body weight of the birds in the respective pen, and the resulting weight was recorded as the live body weight. The bird was then sacrificed using carbon dioxide for the evaluation of some carcass characteristics. The head and the shanks were then separated at the first cervical vertebra and the ankle joint, respectively [32]. The birds were then weighed, and the resulting value was recorded as the hot carcass weight [33]. The carcass percentage was then calculated using the hot carcass weight as a percentage of the live body weight. Subsequently, the breast muscle and drumstick were separated by experienced personnel and also weighed for evaluation of their relative percentages to the total carcass. They were then deboned and stored for proximate composition analyses. Assessments were then done for the breast and drumstick dry matter, crude protein, crude fat, and ash as well as the pH using standard procedures [34].

Statistical Analyses

Collected data were analyzed for statistical significance at $p < 0.05$ using the one-way ANOVA technique. The pen and the sacrificed birds were used as the experimental units for the evaluation of the growth performance indices and the carcass characteristics that were measured, respectively. When statistical significance was noted for the effect of the different bedding materials on the measured parameters, the means were separated using Tukey's multiple range test.

Results

Growth Performance

With routine management, the birds exhibited normal behavior and remained healthy throughout the entire 42-day period. Overall, the condition of ducks reared, regardless of the bedding provided was good with no disease incidences or mortalities being reported. The effects of the different commercially available bedding materials on the growth performance parameters of White Pekin ducks are recorded in Table 1. Higher body weights ($p < 0.05$) were noticed with rice husks on day 42 only with no significant effects nor trends ($0.05 < p < 0.10$) being noted for all the previous days (d 7, 14, 21,28, and 35). Improved daily gains ($p < 0.05$) were also noticed for birds raised with rice husks over the entire period (days 1-42) only with no major effects being noted in previous days and phases.

Concerning the feed intake, improved ADFI values ($p < 0.05$) were similarly noted with rice husks for the grower phase (d 22-42), and the entire experimental period (d 1-42). Marginally improved feed intake values were noted with the use of rice husks as the bedding materials on d 42 ($p = 0.092$). For the FCR, lower values ($p < 0.05$) that improved feed efficiency were noted with birds raised using the rice husks as the bedding material on d 35, the grower period, and the entire 42-day period. A marginal effect for improved feed efficiency with rice husks was also noticed on day 42 ($p = 0.077$).

Carcass characteristics

Effects of the different bedding materials on the carcass, breast, and drumstick percentages as well as the breast and drumstick proximate values are recorded in Table 2. The relative percentages for the total carcass, breast, and drumstick muscles for birds raised under rice husks were numerically higher than those raised under cocopeat and sawdust. However, neither significance nor trends ($0.05 < p < 0.10$) were noted. Similarly for the proximate analyses, neither significant effects nor trends ($0.05 < p < 0.10$) were noted for all the parameters that were measured in both the drumstick and breast muscle. Nevertheless, reduced ($p < 0.05$) pH values for the breast were noticed with the use of rice husks as the bedding.

Discussion

Farghly et al. [35] have exhaustively enumerated that bedding materials should preferably be cheap, easily available, suitable for use as fertilizer, and comfortable enough to allow the birds to walk on them. An ideal bedding material should also have low moisture content (MC), high water adsorption capacity, reduced ammonia emissions and thermal conductivity, short drying time for quick release of absorbed water to prevent caked and wet bedding incidences, low pH to prevent the proliferation of pathogens in the litter, and a lightweight property for ease of handling [35, 36]. Considering the demonstrated impact of the living environment on productive indices [5, 17] and the fact that ducks spend their entire growth period in contact with the bedding materials, we were specifically interested in determining whether different bedding materials could have varied effects on the growth performance and carcass characteristics of White Pekin ducks. Three different commercially available beddings made of coco peat, rice husks, and sawdust were evaluated in this study.

Determining the impact of bedding on productive indices such as growth performance could provide grounds for recommending suitable materials with possible advantageous impact on production, if all other factors such as availability and cost-effectiveness are kept constant. In conformance with Anisuzzaman and Chowdhury [37], the use

of rice husk bedding materials for ducks in the current study exerted a desired incremental impact on the growth performance of ducks. The increased effect could be attributed to increased feed intake and efficiency of conversion of the consumed feed into lean muscle. A higher daily weight gain and elevated body weight were noted when rice husk was provided as the bedding material for the ducks. This inference could be important and relevant to paddy-producing countries such as South Korea, where the use of rice husks as bedding material for broiler chickens and ducks is predominant at approximately 85% [38].

Similar to chicks, hatched ducklings also deal with a transition to aerial breathing, the onset of independent thermal regulation, and a shift from a yolk-based lipid nutrient supply to an exogenous diet that is predominantly carbohydrate-based [39]. The first seven days of growth has a huge impact on the survivability and performance of the flock [40]. In this study, the growth performance of the birds in the first week and the subsequent four weeks showed that dissimilar bedding materials had no significant influences on the ducks. This could be attributed to the ability of all three bedding materials to support the survival of and be compatible with ducklings with no significant effects on the performance of ducks within the first five weeks.

In addition, suitable bedding materials should be devoid of harmful contaminants such as toxins, molds, or pathogens, as birds are known to occasionally feed on the material provided [35, 41]. A similar observation has been reported by Musa et al. [42], who noted that birds could eat up to 4% of the provided litter. Considering that rice husk bedding had an incremental impact on duck growth performance at the later stages (week 6), the relative consumption of rice husks in their dry form from the bedding material could have a possibly unintended or previously unforeseen beneficial effect as ducks occasionally feed on them. Moreover, ducks can cope well with the consumption of highly fibrous material in their diet as has been reported [43]; nevertheless, further investigations are imperative. The consumption of high-fibre constituents such as rice husks could have gut-health-promoting effects [44], but have a limiting effect on nutrient digestibility, which could be accompanied by higher faecal weight and frequency due to a reduced nutrient transit time in the gut [43]. Faster feed passage in the gut could translate to a resulting increase in feed intake as a compensative strategy [44] as was noted in the increased daily feed intake of the ducks raised using rice husks.

The carcass characteristics were analyzed, and we found that the use of dissimilar bedding materials did not exert a profound impact on most of the parameters measured. The pH of leg and breast muscle samples was evaluated as it is one of the core determinants of muscle quality. No variations were noted in the leg muscle. However, an unexpected and significant impact of the rice bedding material, which has a lower pH value, was noted on breast muscle. pH is a function of the amount of glycogen before slaughter and the conversion rate of glycogen to lactic acid [45]. Lower pH could therefore point to a variation in glycolytic metabolism due to dissimilar bedding material; hence, further studies on pH and other carcass traits that could be subject to pH, such as muscle color, water-holding capacity, and cooking loss percentages, are necessary.

In conclusion, the type of bedding material provided could have a significant impact on the growth performance of ducks. The use of rice husks as an alternative bedding material had a positive impact on indices of growth performance for White Pekin ducks for 42 days and is therefore recommended. Further research on the effects of different commercially available bedding materials on performance, ammonia emissions, stress indicators, faecal microbiota and other meat quality parameters is recommended.

Acknowledgments

The authors greatly appreciate the financial and material support provided by the Ministry of Agriculture, Feed and Rural Affairs.

References

1. Ali MS, Kang G-H, Yang H-S, Jeong J-Y, Hwang Y-H, Park G-B, et al. A Comparison of Meat Characteristics between Duck and Chicken Breast. Asian-Australasian Journal of Animal Science. 2007;20(6):1002-6. https://doi.org/10.5713/ajas.2007.1002

2. Wickramasuriya SS, Yi Y-J, Yoo J, Kang NK, Heo JM. A review of canola meal as an alternative feed ingredient for ducks. Journal of Animal Science and Technology. 2015;57(1):29. https://doi.org/10.1186/s40781-015-0062-4

3. Kim H-J, Son J, Kim H-S, Hong E-C, Kim J-H. Effects of light intensity on growth performance, blood components, carcass characteristics, and welfare of broilers. Journal of Animal Science and Technology. 2022;64(5):985-96. https://doi.org/10.5187/jast.2022.e47

4. Ravindran V. Advances and Future Directions in Poultry Nutrition: An Overview. Korean Journal of Poultry Science. 2012;39. https://doi.org/10.5536/KJPS.2012.39.1.053

5. Jimoh OA, Daramola OT, Okin-Aminu HO, Ojo OA. Performance, hemato-biochemical indices and oxidative stress markers of broiler chicken fed phytogenic during heat stress condition. Journal of Animal Science and Technology. 2022;64(5):970-84. https://doi.org/10.5187/jast.2022.e46

6. Abo Ghanima MM, Abd El-Hack ME, Taha AE, Tufarelli V, Laudadio V, Naiel MAE. Assessment of Stocking Rate and Housing System on Performance, Carcass Traits, Blood Indices, and Meat Quality of French Pekin Ducks. Agriculture. 2020;10(7):273. https://www.mdpi.com/2077-0472/10/7/273

7. Cengiz Ö, Hess JB, Bilgili SF. Effect of bedding type and transient wetness on footpad dermatitis in broiler chickens. Journal of Applied Poultry Research. 2011;20(4):554-60. https://doi.org/10.3382/japr.2011-00368

8. Abdel-Hamid SE, Saleem AY, Youssef MI, Mohammed HH, Abdelaty AI. Influence of housing systems on duck behavior and welfare. Journal of Advanced Veterinary Animal Research. 2020;7(3):407-13. https://doi.org/10.5455/javar.2020.g435

9. Li H, Wen X, Alphin R, Zhu Z, Zhou Z. Effects of two different broiler flooring systems on production performances, welfare, and environment under commercial production conditions. Poultry Science. 2017;96(5):1108-19. https://doi.org/10.3382/ps/pew440

10. Shepherd EM, Fairchild BD, Ritz CW. Alternative bedding materials and litter depth impact litter moisture and footpad dermatitis. Journal of Applied Poultry Research. 2017;26(4):518-28. https://doi.org/10.3382/japr/pfx024

11. Toledo TDSD, Pich CS, Roll AAP, Dai Prá MA, Leivas Leite F, Gonçalves Xavier E, et al. The effect of litter materials on broiler performance: a systematic review and meta-analysis. British Poultry Science. 2019;60(6):605-16. https://doi.org/10.1080/00071668.2019.1639143

12. Sharma G, Khan A, Singh D, Anand A. Efficacy of pine leaves as an alternative bedding material for broiler chicks during summer season. Veterinary World. 2015; 8:1219-24. https://doi.org/10.14202/vetworld.2015.1219-1224

13. Davis JD, Purswell JL, Kiess AS. Evaluation of chopped switchgrass and chopped bermudagrass as litter materials over multiple heavy broiler flocks[1]. Journal of Applied Poultry Research. 2015;24(3):343-51. https://doi.org/10.3382/japr/pfv034

14. Kheravii SK, Swick RA, Choct M, Wu SB. Potential of pelleted wheat straw as an alternative bedding material for broilers. Poultry Science. 2017;96(6):1641-7. https://doi.org/10.3382/ps/pew473

15. Watts DB, Hess JB, Bilgili SF, Torbert HA, Sibley JL, Davis JD. Flue gas desulfurization gypsum: Its effectiveness as an alternative bedding material for broiler production. Journal of Applied Poultry Research. 2017;26(1):50-9. https://doi.org/10.3382/japr/pfw045

16. Bilgili SF, Montenegro GI, Hess JB, Eckman MK. Sand as Litter for Rearing Broiler Chickens[1]. Journal of Applied Poultry Research. 1999;8(3):345-51. https://doi.org/10.1093/japr/8.3.345

17. Mohammed H, Abdelaty A, Saleem A-S, Youssef M, Abdel-Hamid S. Effect of bedding materials on duck's welfare and growth performance. Slovenian Veterinary Research. 2019;56(22-Suppl). https://doi.org/10.26873/SVR-752-2019

18. Garcês A, Afonso SMS, Chilundo A, Jairoce CTS. Evaluation of different litter materials for broiler production in a hot and humid environment: 1. Litter characteristics and quality. Journal of Applied Poultry Research. 2013;22(2):168-76. https://doi.org/10.3382/japr.2012-00547

19. de Jong IC, Gunnink H, van Harn J. Wet litter not only induces footpad dermatitis but also reduces overall welfare, technical performance, and carcass yield in broiler chickens. Journal of Applied Poultry Research. 2014;23(1):51-8. https://doi.org/10.3382/japr.2013-00803

20. Dunlop MW, McAuley J, Blackall PJ, Stuetz RM. Water activity of poultry litter: Relationship to moisture content during a grow-out. Journal of Environmental Management. 2016; 172:201-6. https://doi.org/10.1016/j.jenvman.2016.02.036

21. Garcia R, Almeida Paz I, Caldara F, Nääs I, Df P, Oliveira dos Santos V, et al. Selecting the Most Adequate Bedding Material for Broiler Production in Brazil. Revista Brasileira de Ciência Avícola. 2012; 14:71. https://doi.org/10.1590/S1516-635X2012000200006

22. Garcês APJT, Afonso SMS, Chilundo A, Jairoce CTS. Evaluation of different litter materials for broiler production in a hot and humid environment: 2. Productive performance and carcass characteristics. Tropical Animal Health and Production. 2017;49(2):369-74. https://doi.org/10.1007/s11250-016-1202-7

23. Malone B. Managing built-up bedding. Proceedings of the Virginia Health and Management Seminar; 2004.

24. Asoka Panamgama L, Peramune PRUSK. Coconut coir pith lignin: A physicochemical and thermal characterization. International Journal of Biological Macromolecules. 2018; 113:1149-57. https://doi.org/10.1016/j.ijbiomac.2018.03.012

25. Verasoundarapandian G, Zakaria NN, Shaharuddin NA, Khalil KA, Puasa NA, Azmi AA, et al. Coco Peat as Agricultural Waste Sorbent for Sustainable Diesel-Filter System. Plants. 2021;10(11):2468. https://doi.org/10.3390/plants10112468

26. Krishnapillai M, Young-Uhk S, Friday J, Haase D. Locally Produced Cocopeat Growing Media for Container Plant Production. Tree Planters' Notes. 2020; 63:29-38. Available from https://rngr.net/publications/tpn/63-1

27. Udayana S, Naorem A, Singh N. The Multipurpose Utilization of Coconut By-Products in Agriculture: Prospects and Concerns. International Journal of Current Microbiology and Applied Sciences. 2017; 6:1408-15. https://doi.org/10.20546/ijcmas.2017.606.165

28. Casas Bedoya GA. Nutritional evaluation of rice coproducts fed to pigs: University of Illinois at Urbana-Champaign; 2018.

29. Chand N, Fahim M. 1 - Natural fibers and their composites. In: Chand N, Fahim M, editors. Tribology of Natural Fiber Polymer Composites (Second Edition): Woodhead Publishing; 2021. p. 1-59. https://doi.org/10.1016/B978-0-12-818983-2.00001-3

30. Abazari A, Navidshad B, Mirzaei Aghjehgheshlagh F, Nikbin S. The effect of rice husk as an insoluble dietary fiber source on intestinal morphology and Lactobacilli and Escherichia coli populations in broilers. Iranian Journal of Veterinary Medicine. 2016;10(3):217-24. Available from https://ijvm.ut.ac.ir/article_58684_6ec72126a3f2f5afd73027d0582dc94d.pdf

31. Munir MT, Belloncle C, Irle M, Federighi M. Wood-based litter in poultry production: a review. World's Poultry Science Journal. 2019;75(1):5-16. https://doi.org/10.1017/S0043933918000909

32. Biesek J, Banaszak M, Kuźniacka J, Adamski M. Characteristics of carcass and physicochemical traits of meat from male and female ducks fed a diet based on extruded soybean. Poultry Science. 2021;100(7):101170. https://doi.org/10.1016/j.psj.2021.101170

33. Oketch EO, Lee JW, Yu M, Hong JS, Kim YB, Nawarathne SR, et al. Physiological responses of broiler chickens fed reduced-energy diets supplemented with emulsifiers. Animal Bioscience. 2022;35(12):1929-39. https://doi.org/10.5713/ab.22.0142

34. AOAC I. Association of Official Analytical Chemists, Official Methods of Analysis of AOAC International. Gaithersburg, USA; 2015.

35. Farghly MFA, Mahrose KM, Cooper RG, Metwally KA, Abougabal MS, El-Ratel IT. Use of available crop by-products as alternative bedding materials to wheat straw for rearing broilers. Animal. 2021;15(7):100260. https://doi.org/10.1016/j.animal.2021.100260

36. Bilgili SF, Hess JB, Blake JP, Macklin KS, Saenmahayak B, Sibley JL. Influence of bedding material on footpad dermatitis in broiler chickens. Journal of Applied Poultry Research. 2009;18(3):583-9.

37. Anisuzzaman M, Chowdhury SD. Use of four types of litter for rearing broilers. British Poultry Science. 1996;37(3):541-5. https://doi.org/10.1080/00071669608417883

38. Yu J-S. 깔짚의 올바른 선택과 사양관리 방안. Korean Poultry Journal. 2005;37(10):72-6. Available from https://koreascience.kr/article/JAKO200565771846413.page

39. Christensen VL. Development during the First Seven Days Post-hatching. Avian Biology Research. 2009;2(1-2):27-33. https://doi.org/10.3184/175815509X430417

40. Yassin H, Velthuis AGJ, Boerjan M, van Riel J. Field study on broilers' first-week mortality. Poultry Science. 2009;88(4):798-804. https://doi.org/10.3382/ps.2008-00292

41. Ritz CW, Fairchild BD, Lacy MP. Litter quality and broiler performance. 2009. Available from https://hdl.handle.net/10724/12466

42. Musa I, Sáidu L, Yunusa K, Abubakar UB, Wakawa AM. Poultry Litter Selection, Management and Utilization in Nigeria. Asian Journal of Poultry Science. 2012; 6:44-55.

43. Fadil M, Alimon AR, Meng GY, Ebrahimi M, Farjam AS. Palm Kernel Cake as a Potential Ingredient in Muscovy Ducks Diet. Italian Journal of Animal Science. 2014;13(1):3035. https://doi.org/10.4081/ijas.2014.3035

44. Jha R, Fouhse JM, Tiwari UP, Li L, Willing BP. Dietary Fiber and Intestinal Health of Monogastric Animals. Frontiers in Veterinary Science. 2019;6. https://doi.org/10.3389/fvets.2019.00048

45. Mir NA, Rafiq A, Kumar F, Singh V, Shukla V. Determinants of broiler chicken meat quality and factors affecting them: a review. Journal of Food Science and Technology. 2017;54(10):2997-3009. https://doi.org/10.1007/s13197-017-2789-z

319 **Tables and Figures**

320 **Table 1**. Effects of different bedding materials on the growth performance of White Pekin ducks[1]

	Cocopeat	Rice husks	Sawdust	SEM[2]	*p*-value[3]
Body weight, g					
Day 1	60.48	60.44	60.39	0.163	0.973
Day 7	277.89	302.13	298.31	5.938	0.206
Day 14	803.91	849.12	827.72	9.751	0.169
Day 21	1409.23	1439.91	1404.44	11.902	0.437
Day 28	2175.28	2250.71	2168.58	26.013	0.375
Day 35	3189.68	3263.10	3181.57	22.435	0.273
Day 42	3781.75[a]	3964.15[b]	3828.14[ab]	32.327	0.049
Average daily gain, g/d					
Day 7	31.06	34.52	33.98	0.848	0.206
Day 14	75.14	78.14	75.63	1.000	0.441
Day 21	86.47	84.40	82.39	1.463	0.543
Day 28	109.44	115.83	109.16	2.881	0.586
Day 35	169.07	168.73	168.83	3.296	0.999
Day 42	84.58	100.15	92.37	3.800	0.256
Day 1-21	64.23	65.69	64.00	0.567	0.437
Day 22-42	112.98	120.20	115.41	1.470	0.123
Day 1-42	88.60[a]	92.94[b]	89.71[ab]	0.770	0.049
Average daily feed intake, g/d					
Day 7	36.00	37.31	36.11	0.994	0.667
Day 14	106.36	107.05	106.57	0.123	0.738
Day 21	155.28	156.77	153.06	0.868	0.221
Day 28	237.98	231.80	233.17	2.928	0.683
Day 35	383.23	388.73	370.06	2.039	0.431
Day 42	246.32	262.69	253.92	4.109	0.092
Day 1-21	95.88	100.37	97.25	0.699	0.109
Day 22-42	269.18[a]	289.07[b]	270.72[a]	5.879	0.007
Day 1-42	180.53[a]	195.72[b]	188.48[ab]	3.936	0.037
Feed conversion ratio, g/g					
Day 7	0.98	0.93	0.94	0.014	0.341
Day 14	1.34	1.37	1.36	0.013	0.560
Day 21	1.80	1.88	1.86	0.026	0.449

Day 28	2.19	2.03	2.16	0.044	0.301
Day 35	2.66[b]	2.31[a]	2.56[ab]	0.060	0.036
Day 42	3.46	2.59	2.84	0.165	0.077
Day 1-21	1.49	1.53	1.52	0.012	0.422
Day 22-42	2.67[b]	2.26[a]	2.48[ab]	0.058	0.008
Day 1-42	2.24[b]	2.00[a]	2.14[ab]	0.034	0.009

[1)]Values are the mean of eight replicate pens per bedding material

[2)]Pooled standard error of the mean

[3)]Statistical significance was determined at $p < 0.05$

[a-b)] Means with different superscripts within the same column differ significantly

Table 2. Effects of different bedding materials on carcass characteristics of White Pekin ducks[1]

Item	Cocopeat	Rice husks	Saw dust	SEM[2]	*p* -value[3]
Carcass relative percentages, %					
Carcass	87.74	88.07	87.93	0.463	0.962
Breast	18.43	18.68	18.51	0.373	0.966
Drumstick	5.63	5.90	5.73	0.097	0.520
Drumstick proximate analyses, %					
Dry matter	64.61	66.91	68.79	1.0913	0.319
Crude protein	19.16	18.15	19.45	0.311	0.212
Crude fat	11.16	12.44	10.15	0.683	0.430
Ash	1.36	1.13	1.25	0.046	0.116
pH	5.55	5.54	5.57	0.009	0.534
Breast proximate analyses, %					
Dry matter	70.50	72.39	70.05	0.640	0.309
Crude protein	21.80	21.20	21.01	0.213	0.318
Crude fat	1.47	1.77	1.49	0.117	0.544
Ash	1.63	1.62	1.59	0.047	0.949
pH	5.97[b]	5.92[a]	5.96[b]	0.008	0.001

[1)] Values are the mean of eight replicate pens per bedding material

[2)] Pooled standard error of the mean

[3)] Statistical significance was determined at $p < 0.05$

[a-b)] Means with different superscripts within the same column differ significantly