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Effects of Perch Cooling and Litter Thickness on the Tibial Biomechanical Properties of Broiler Chickens

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ABSTRACT

This study aimed to evaluate the effects of perch type and litter thickness on the biomechanical properties of the tibia in broiler chickens. The experiment was conducted as a 3 × 3 factorial design with three perch treatments (no perch, non-cooled perch, and cooled perch) and three litter depths (1, 7, and 14 cm), yielding nine treatment combinations. On day 42, left tibias from seven birds per replicate compartment (total n = 189) were collected and subjected to a three-point bending test to determine maximum force (Fmax), stiffness, strength, and elastic modulus. Broilers provided with cooled perches exhibited significantly higher Fmax values (290.930 ± 8.234 N) compared with other perch treatments ($P < 0.05$). Litter thickness did not significantly influence tibial Fmax or other mechanical parameters. The findings indicate that cooled perches, together with a moderate litter depth (7 cm), may contribute to slightly improved tibial mechanical performance. Further studies involving additional long bones and different enrichment designs are required to clarify the extent of these effects on skeletal quality.

Keywords: Biomechanics, Broiler, Litter thickness, Perch, Tibia.

Soğuk Tünek ve Altlık Kalınlığının Etlik Piliçlerde Tibial Biyomekanik Özellikleri Üzerine Etkileri

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ÖZ

Bu çalışma, tünek tipi ve altlık kalınlığının etlik piliçlerde tibianın biyomekanik özellikleri üzerindeki etkilerini değerlendirmeyi amaçlamıştır. Deneme, üç tünek uygulaması (tüneksiz, soğutmasız ve soğutmalı tünek) ile üç altlık derinliğinin (1, 7 ve 14 cm) yer aldığı 3 × 3 faktöriyel düzende planlanmış olup, toplamda dokuz farklı deneme kombinasyonu elde edilmiştir. Denemenin 42. gününde, her bir tekerrür bölmesinden yedi pilice ait sol tibialar (toplam n = 189) toplanmış ve maksimum kuvvet (Fmax), rijitlik, dayanım ve elastik modülü belirlemek amacıyla üç nokta eğme testine tabi tutulmuştur. Soğutmalı tünek bulunan grupta Fmax değerleri (290.930 ± 8.234 N), diğer tüneklik uygulamalarına kıyasla anlamlı düzeyde daha yüksek bulunmuştur ($P < 0.05$). Altlık kalınlığının Fmax ve diğer mekanik parametreler üzerinde anlamlı bir etkisi belirlenmemiştir. Bulgular, soğutmalı tüneklerin özellikle orta düzey altlık derinliği (7 cm) ile birlikte kullanıldığında tibial mekanik performansı bir miktar artırabileceğini göstermektedir. İskelet kalitesine ilişkin etkilerin daha net anlaşılabilmesi için farklı uzun kemiklerin ve çeşitli çevresel zenginleştirme uygulamalarının değerlendirildiği ileri araştırmalara ihtiyaç vardır.

Anahtar Kelimeler: Altlık kalınlığı, Biyomekanik, Etlik piliç, Tibia, Tünek.

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Introduction

Rapid genetic progress and selection for accelerated growth have increasingly compromised skeletal health in modern broiler chickens. As birds reach heavy body weights within a short period, they exhibit markedly reduced activity, spending up to 80% of their time inactive (Weeks et al., 2000). This limited mobility is considered a major contributor to skeletal disorders and impaired bone development (Bailie & O'Connell, 2015). Several management approaches—such as optimizing feeding, watering, and lighting systems—have therefore been investigated to stimulate locomotor activity in broilers.

Broiler genotypes, characterized by rapid growth and high breast muscle yield, are commonly associated with reduced locomotor activity and a higher incidence of welfare-related disorders, including lameness, foot pad dermatitis, and breast blisters. Among these, lameness is considered one of the most significant production and ethical concerns, as impaired walking ability can reduce access to feed and water and increase discomfort. In addition, prolonged contact with wet or poor-quality litter may predispose birds to foot pad dermatitis and hock lesions, while extended resting on the sternum can contribute to the development of breast blisters and breast

skin damage. These conditions are closely linked with inactivity, housing environment, and litter management, indicating that production systems encouraging movement and improving floor conditions may contribute to better welfare and skeletal outcomes (Bessei, 2006; Bailie et al., 2018; Mayne, 2005).

Environmental enrichment with perches represents one such modification aimed at encouraging natural behaviors (Riber et al., 2018). Roosting is an inherent behavioral trait in poultry, and research has demonstrated that access to perches improves activity, welfare, and performance in laying hens (Hu, 2017; Hu et al., 2021; Wang et al., 2019). Broilers, although heavier and less agile, also display perching tendencies, particularly around the fourth week of age (Shields et al., 2005).

Cooled perches have mainly been evaluated as an environmental intervention to alleviate heat load in poultry, as conductive heat loss through the feet and shanks may reduce body thermal burden and improve welfare outcomes under warm conditions (Zhao et al., 2012; Hu et al., 2019; Hu et al., 2021). Previous studies have reported beneficial effects of cooled perches on performance, welfare, and behavioral responses during heat exposure (Dereli Fidan et al., 2020a, Dereli Fidan et al., 2020b). Nevertheless, cooled perches may also modify perch preference, resting distribution, and bird–environment interactions, potentially influencing locomotor behavior and mechanical stimulation of the legs (Pettit-Riley & Estevez, 2001).

Recent findings by Dereli Fidan et al. (2021) demonstrated that cooled perches and increased litter depth influenced leg health and several morphometric bone characteristics in broiler chickens. Similar observations have also been reported in studies examining the effects of environmental management on skeletal development and leg-related traits in poultry (Birgül et al., 2012; Kiyma et al., 2016; Kaukonen et al., 2017; Süzer et al., 2019; Sevinç and Yılmaz Dikmen, 2026). Although the previous study primarily evaluated tibial dimensions and geometric indices, biomechanical testing provides more direct functional information regarding bone resistance to loading, fracture tolerance, and structural competence. Therefore, the present study was designed to determine whether those previously reported management effects were also reflected in the biomechanical properties of the broiler tibia. In addition, litter depth may influence broiler welfare and skeletal development through modifications in floor cushioning, perch accessibility, moisture retention, and locomotor comfort. The present study also evaluated whether cooled perches, beyond their thermoregulatory role, could be associated with measurable changes in tibial biomechanical properties when combined with different litter depths.

Litter characteristics constitute another critical component of the housing environment. Proper bedding facilitates moisture evaporation and helps prevent conditions conducive to bacterial growth (El-Wahab et al., 2011). Consequently, litter type, moisture level, and ammonia concentration are fundamental factors influencing broiler welfare (Mayne, 2005). Appropriate bedding may additionally promote natural behaviors and enhance mobility.

Both perches and litter quality are therefore considered essential elements of broiler housing systems, with combined effects on behavior, bone loading, and musculoskeletal development (Bailie et al., 2018). Increased physical activity associated with these enrichments may strengthen leg bones by promoting more consistent mechanical stimulation (Velo and Ceular, 2017).

Accordingly, the aim of the present study was to determine whether perch type (no perch, non-cooled perch, and cooled perch) and litter depth (1, 7, and 14 cm) would exert measurable effects on tibial biomechanical properties in fast-growing broiler chickens. We hypothesized that environmental modifications promoting greater comfort, perch interaction, and locomotor activity would enhance mechanical loading of the legs and result in improved tibial strength characteristics.

Materials and Methods

Ethical Statement

The experiments were conducted in strict compliance with the ethical guidelines of Aydın Adnan Menderes University (Approval No: 64583101/2017/049, Approval Date: 13/06/2017).

Animals and Experimental Design

A total of 459 one-day-old male Ross 308 broiler chicks obtained from a commercial hatchery (EGE-TAV Agriculture and Livestock Investment Trade and Industry Inc., Izmir, Türkiye) were randomly assigned to nine treatment groups in a 3 × 3 factorial arrangement. The experimental factors consisted of three perch treatments (no perch, non-cooled perch, and cooled perch) and three litter thicknesses (1, 7, and 14 cm). These litter depths were selected to represent shallow, moderate, and deep bedding conditions, respectively, reflecting practical variation in bedding management. In addition, they were intended to modify the effective perch-to-floor distance and floor surface characteristics, which may influence bird mobility and tibial loading.

Each combination of perch type and litter depth represented one experimental treatment group. All groups were reared under the same management and environmental conditions throughout the 42-day experimental period. Brooding temperature was initially maintained at approximately 34°C during the first 3 days and gradually reduced to around 30°C by the end of the first week. Thereafter, birds were exposed to prevailing summer ambient temperatures during the grower-finisher period. In companion publications based on the same experimental population, daily mean ambient temperatures ranged from approximately 30.4 to 31.9°C, while maximum diurnal temperatures reached approximately 33.4 to 34.2°C, with relative humidity generally between 50 and 60%. A standard lighting schedule, routine ventilation management, and identical husbandry procedures were applied across all groups.

Feed and water were provided *ad libitum*, birds received the same age-phase commercial diets, and stocking density was equal among treatments. Only perch treatment and litter depth differed experimentally.

Bone Biomechanical Properties

At day 42, left tibias were randomly collected from seven clinically healthy birds per replicate compartment (total n = 189) for biomechanical evaluation. In Figure 1, a three-point bending test was performed to determine maximum force (Fmax), stiffness, strength, and elastic modulus using a Zwick/Roell universal mechanical testing machine, following ANSI/ASABE Standard S459 (Standards, 2003). The span between the two supports was set at 50 mm. Force was applied at the midpoint on the caudal surface of each bone. A pre-load of 2 N was used, and the crosshead speed was maintained at 10 mm/min. All force–displacement data were recorded using testXpert® II software.

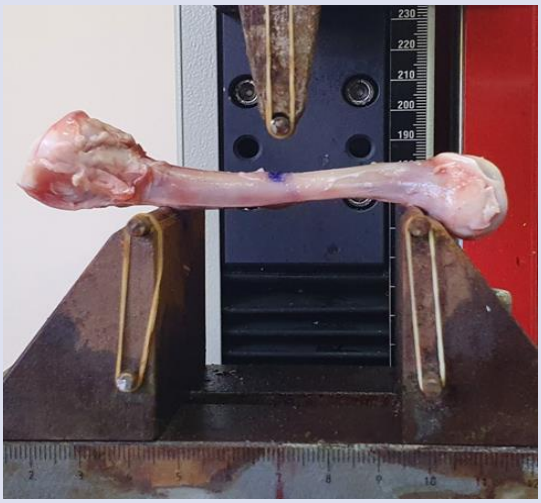

Figure 1. Three-point bending test setup showing the positioning of the tibia on the Zwick/Roell mechanical testing apparatus.

Statistical Analysis

Statistical analyses were performed using SPSS version 22.0 (SPSS Inc., Chicago, IL, USA). Prior to all analyses, the distribution of the data was evaluated using the Shapiro–Wilk test, and homogeneity of variances was assessed using Levene's test. Variables meeting parametric assumptions were analyzed using a Generalized Linear Model (GLM) with a normal distribution and identity link function. The fixed effects in the model were perch type (no perch, non-cooled perch, and cooled perch), litter thickness (1, 7, and 14 cm), and their interaction. The statistical model was structured as:

$$Y_{ijk} = \mu + P_i + L_j + (P \times L)_{ij} + e_{ijk}$$

where Y_{ijk} is the response variable, μ is the overall mean, P_i is the effect of perch type, L_j is the effect of litter thickness, $(P \times L)_{ij}$ is the interaction term, and e_{ijk} is the residual error. When significant main effects were detected, pairwise comparisons were conducted using Tukey's post-hoc test to control for Type I error. Results are presented as least square means (LSmeans) ± standard error of the mean (SEM). Statistical significance was accepted at $P < 0.05$.

Results and Discussion

The biomechanical analysis showed that perch treatment had a significant effect on maximum force (Fmax). Broilers provided with cooled perches exhibited the highest Fmax values (290.930 ± 8.234 N; $P < 0.05$) (Table 1). In contrast, deformation at failure did not differ among perch groups. The biomechanical characteristics of a bone depend on both its material composition and geometric properties, such as shape, length, and diaphyseal diameter. The absence of significant differences among groups in the present study may therefore be related to the previously reported lack of change in tibial dimensions under similar enrichment conditions (Dereli Fidan et al., 2021). Improvements in tibial strength have been documented in laying hens following perch use; however, broilers often fail to exhibit comparable benefits due to their limited mobility and rapid weight gain (Bizeray et al., 2002). Similar findings have been reported in turkeys, where litter management strategies did not sufficiently overcome leg weakness (Hester et al., 1987). Although cooled perches are most commonly associated with heat-load mitigation, the higher maximum force values observed in the present study suggest that such structures may also influence bone-related outcomes through indirect pathways, including altered perch use, posture, resting behavior, or activity distribution. These potential mechanisms require further behavioral confirmation.

The higher maximum force values observed in birds provided with cooled perches are in agreement with the findings of Dereli Fidan et al. (2021), who reported improvements in leg health and selected bone traits under comparable management conditions. Collectively, these results indicate that environmental modifications, such as perch cooling, may affect not only external welfare indicators but also internal skeletal integrity. Given that the birds were reared under practical summer conditions rather than controlled thermoneutral environments, these findings should be interpreted within the context of commercial broiler production systems. Therefore, the observed effects of cooled perches on tibial biomechanical traits are likely attributable to a combination of environmental interactions and behavioral responses, in addition to direct thermal influences.

Broilers tend to spend much of their time lying due to their high body mass, and cooled perches have been shown to further increase body weight (Dereli Fidan et al., 2021; Zhao et al., 2012). Although broilers may initially show interest in perching, their ability to maintain this behavior likely diminishes as their body weight increases and locomotor limitations arise. Previous studies indicate that perch use in broilers is influenced by perch placement and elevation level (LeVan et al., 2000). Estevez et al. (2002) reported that younger broilers prefer low perches

but shift toward higher elevations as they approach 5–6 weeks of age. In the present study, a fixed perch height of 10 cm was used across treatments, while only litter depth varied. Providing a wider range of perch elevations in combination with different litter thicknesses may therefore enhance activity and skeletal loading more effectively.

Litter thickness (1, 7, and 14 cm) did not significantly influence Fmax or any other mechanical parameter. Similarly, stiffness, strength, and elastic modulus values calculated from the force–displacement curves showed no significant differences among treatments ($P > 0.05$). All measured variables are presented in Table 1. Consistent with earlier research in turkeys (Hester et al., 1987), litter thickness did not affect tibial biomechanical traits, suggesting that floor height alone is insufficient to induce the level of movement required to influence bone strength. The present findings indicate that providing thicker bedding or moderate adjustments to perch height does not ensure meaningful improvements in bone quality in fast-growing broilers. As emphasized in previous literature, litter management alone cannot compensate for the limited mobility characteristic of modern broiler strains (Hester et al., 1987).

Table 1. Effects of perch type and litter thickness on the biomechanical properties of the left tibia in broiler chickens.

Item	Maximum Force (N)	Deformation (mm)	Stiffness (N/mm)	Strength (MPa)	Elastic Modulus (MPa)
Expected Mean (μ)	271.838	4.463	91.293	84.118	1645.412
Perch					
No Perch	260.277^{c}±7.578	4.538±0.099	87.43^{c}±2.176	81.901±2.156	1599.405±65.097
Normal Perch	264.307^{b}±8.185	4.529±0.107	90.458^{b}±2.351	85.856±2.329	1753.001±70.318
Cold Perch	290.930^{a}±8.234	4.322±0.107	96.378^{a}±2.365	84.595±2.343	1583.831±70.737
Litter Thickness					
1 cm	274.075±8.309	4.497±0.108	90.348±2.386	81.069±2.364	1539.073±71.380
7 cm	274.078±7.798	4.491±0.102	91.077±2.239	86.427±2.218	1685.459±66.991
14 cm	267.361±7.898	4.401±0.103	92.454±2.268	84.857±2.247	1711.705±67.846
SEM	4.622	0.060	1.327	1.315	39.702
Significance of main effects					
Perch	0.016	0.264	0.016	0.441	0.169
Litter thickness	0.788	0.768	0.808	0.244	0.175
Perch*litter thickness	0.653	0.479	0.433	0.159	0.150

Data are presented as least square means. SEM: pooled standard error of the mean for main effects.
$^{a, b, c}$: Means within the same column bearing different superscripts differ significantly ($P < 0.05$).

Although birds were maintained under thermoneutral commercial rearing conditions, litter quality was not uniform across treatments. Environmental management was applied uniformly across treatments; therefore, potential differences in litter quality were expected to arise mainly from bedding depth, moisture retention, and manure accumulation rather than unequal housing conditions. In a previous study based on the same experimental population (Dereli Fidan et al., 2020b), deeper litter (14 cm) was associated with lower aerial ammonia concentration and reduced litter moisture compared with shallow litter (1 cm).

However, these environmental improvements did not translate into significant differences in most tibial biomechanical parameters in the present study, suggesting that moderate changes in litter condition alone may be insufficient to substantially modify skeletal mechanical integrity. Under adequately managed commercial housing conditions, welfare consequences associated with the treatments are therefore more likely related to locomotion opportunity, resting comfort, perch use, and litter surface characteristics than to severe climatic stress alone.

Several limitations should be acknowledged when interpreting the present findings. Although litter moisture and ammonia concentration were evaluated in companion studies based on the same experimental population, these variables were not simultaneously integrated with the present biomechanical analyses. In addition, direct measurements of perch use frequency and behavioral activity were not recorded during biomechanical testing. Therefore, the mechanisms linking environmental enrichment to tibial biomechanical responses could not be fully quantified.

Conclusions

The present study provides useful biomechanical evidence that cooled perch systems may contribute to improved tibial load resistance in broiler chickens, thereby providing a practical basis for future enrichment strategies aimed at improving skeletal robustness in intensive broiler production systems.

This study demonstrated that the use of cooled perches resulted in a measurable improvement in tibial mechanical performance, particularly reflected by higher maximum force values, whereas litter thickness alone had

no significant effect on any biomechanical parameter. Although cooled perches in combination with a moderate litter depth (7 cm) produced slightly favorable outcomes, these adjustments were insufficient to induce a biologically meaningful enhancement in overall skeletal robustness in fast-growing broilers. The limited impact observed in this study underscores the challenge of improving bone health in broiler strains through single-dimension enrichments. Future studies integrating behavioral monitoring, environmental measurements, and multiple skeletal endpoints would further strengthen understanding of these relationships.

Conflict of Interest Statement

The authors have no relevant financial or non-financial interests to disclose.

Authors' contributions

Evrim Dereli Fidan: Idea/Concept, Supervision/Consultancy, Data Collecting and/or Processing, Analysis and/or Interpretation, Writing The Article, Critical Review. **Komal Khan:** Supervision/Consultancy, Data Collecting and/or Processing, Critical Review. **Mehmet Kaya:** Data Collecting and/or Processing, Writing The Article, Critical Review.

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References

Bailie, C. L, Baxter, M., & O'Connell, N. E. (2018). Exploring perch provision options for commercial broiler chickens. Applied Animal Behaviour Science, 200, 114-122. https://doi.org/10.1016/j.applanim.2017.12.007

Bailie, C. L., & O'Connell, N. E. (2015). The influence of providing perches and string on activity levels, fearfulness and leg health in commercial broiler chickens. Animal, 9(4), 660-668. https://doi.org/10.1017/S1751731114002821

Bessei, W. (2006). Welfare of broilers: a review. World's Poultry Science Journal, 62(3), 455-466.

Birgül, O. B., Mutaf, S. & Alkan, S. (2012). Effects of different angled perches on leg disorders in broilers. European Poultry Science, 76, 44-48. https://doi.org/10.1016/S0003-9098(25)01548-6

Bizeray, D., Estevez, I., Leterrier, C., & Faure, J. (2002). Influence of increased environmental complexity on leg condition, performance, and level of fearfulness in broilers. Poultry Science, 81, 767-773. https://doi.org/10.1093/ps/81.6.767

Dereli Fidan, E., Kaya, M., Nazligul, A., & Turkyilmaz, M. K. (2020a). The effects of perch cooling on behavior, welfare criteria, performance, and litter quality of broilers reared at high temperatures with different litter thicknesses. Brazilian Journal of Poultry Science, 22(3), 1–12. https://doi.org/10.1590/1806-9061-2019-1083

Dereli Fidan, E., Türkyilmaz, M. K., Nazligul, A., & Kaya, M. (2020b). The effects of perch cooling on performance, carcass, and meat quality characteristics and behaviour of broilers reared at high temperatures with different litter thicknesses. Ankara Üniversitesi Veteriner Fakültesi Dergisi, 67, 373–379. https://doi.org/10.33988/auvfd.656030

Dereli Fidan, E., Turkyilmaz, M. K., Nazligul, A., Kaya, M., & Kilimci, F. S. (2021). Effect of perch cooling and litter thickness on leg health and bone characteristics in broilers. Journal of Agricultural Science and Technology, 23(3), 531–544.

El-Wahab, A. A., Beineke, A., Beyerbach, M., Visscher, C., & Kamphues, J. (2011). Effects of floor heating and litter quality on the development and severity of foot pad dermatitis in young turkeys. Avian Diseases, 55, 429-434. https://doi.org/10.1637/9684-021011-Reg.1

Estevez, I., Tablante, N., Pettit-Riley, R., & Carr, L. (2002). Use of cool perches by broiler chickens. Poultry Science, 81, 62-69. https://doi.org/10.1093/ps/81.1.62

Hester, P. Y., Sutton, A. L., & Elkin, R. G. (1987). Effect of light intensity, litter source, and litter management on the incidence of leg abnormalities and performance of male turkeys. Poultry Science, 66, 666-675. https://doi.org/10.3382/ps.0660666

Hu, J. (2017). Thermal Perches as Cooling Devices for Reducing Heat Stress in Caged Laying Hens. (Publication No. 10685206) [Doctoral dissertation, Purdue University]. ProQuest Dissertations and Theses Global.

Hu, J. Y., Hester, P. Y., Makagon, M. M., Xiong, Y., Gates, R. S., & Cheng, H. W. (2019). Effect of cooled perches on performance, plumage condition, and foot health of caged White Leghorn hens exposed to cyclic heat. Poultry science, 98(7), 2705-2718. https://doi.org/10.3382/ps/pez039

Hu, J., Xiong, Y., Gates, R.S., Cheng, H.W. (2021). Perches as cooling devices for reducing heat stress in caged laying hens: A review. Animals, 11, 3026. https://doi.org/10.3390/ani11113026

Kaukonen, E., Norring, M., & Valros, A. (2017). Perches and elevated platforms in commercial broiler farms: use and effect on walking ability, incidence of tibial dyschondroplasia and bone mineral content. Animal, 11, 864-871. https://doi.org/10.1017/S1751731116002160

Kiyma, Z., Küçükyılmaz, K., Orojpour, A. (2016). Effects of perch availability on performance, carcass characteristics, and footpad lesions in broilers. Archives Animal Breeding, 59, 19-25. https://doi.org/10.5194/aab-59-19-2016

LeVan, N. F., Estevez, I., & Stricklin, W. R. (2000). Use of horizontal and angled perches by broiler chickens. Applied Animal Behaviour Science, 65, 349-365. https://doi.org/10.1016/S0168-1591(99)00059-3

Mayne, R. (2005). A review of the aetiology and possible causative factors of foot pad dermatitis in growing turkeys and broilers. World's Poultry Science Journal, 61, 256-267. https://doi.org/10.1079/WPS200458

Pettit-Riley, R., & Estevez, I. (2001). Effects of density on perching behavior of broiler chickens. Applied Animal

Behaviour Science, 71, 127-140. https://doi.org/10.1016/S0168-1591(00)00174-X

Riber, A., Van de Weerd, H., De Jong, I., & Steenfeldt, S. (2018). Review of environmental enrichment for broiler chickens. Poultry Science, 97, 378-396. https://doi.org/10.3382/ps/pex344

Sevinç, B. F. & Yılmaz Dikmen, B. (2026). Perch-based enrichment and broiler growth, welfare and behaviour. Poultry Science, Ahead-of-print, 1-7, https://doi.org/10.1080/00071668.2026.2623990

Shields, S., Garner, J., & Mench, J. (2005). Effect of sand and wood-shavings bedding on the behavior of broiler chickens. Poultry Science, 84, 1816-1824. https://doi.org/10.1093/ps/84.12.1816

Standards, A. (2003). Shear and three-point bending test of animal bone. ANSI/ASAE S459 DEC01, USA.

Süzer, B., Tüfekçi, K., Arıcan, İ., Petek, M., Abdourhamane, İ. M., Özbek, M., & Yıldız, H. (2019). Effects of genotype and housing system on some bone biomechanical characteristics in broiler chickens. Ankara Üniversitesi Veteriner Fakültesi Dergisi, 66(3), 237-246.

Velo, R., & Ceular, A. (2017). Effects of stocking density, light and perches on broiler growth. Animal Science Journal, 88, 386-393. https://doi.org/10.1111/asj.12630

Wang, K., Liu, K., Xin, H., Chai, L., Wang, Y., Fei, T., & Ying, Y. (2019). An RFID-Based Automated Individual Perching Monitoring System for Group-Housed Poultry. Transactions of the ASABE, 62, 695-704. https://doi.org/10.13031/trans.13105

Weeks, C., Danbury, T., Davies, H., Hunt, P., & Kestin, S. (2000). The behaviour of broiler chickens and its modification by lameness. Applied Animal Behaviour Science, 67, 111-125. https://doi.org/10.1016/S0168-1591(99)00102-1

Zhao, J., Jiao, H., Jiang, Y., Song, Z., Wang, X., & Lin, H. (2012). Cool perch availability improves the performance and welfare status of broiler chickens in hot weather. Poultry Science, 91, 1775-1784. https://doi.org/10.3382/ps.2011-02058