Evaluating broiler performance, feather Coverage, activity and feeding hours as affected by growth rate and stocking density

S. Zhou[1], Y. Zhao[1,*], P. Watcharaanantapong[1], X. Yang[1], H. Gan[2], T. Tabler[1], M. Prado[1] and T. Thornton[1]
[1]*Department of Animal Science, University of Tennessee, Knoxville, TN 37996, USA*
[2]*Department of Biosystems Engineering and Soils Science, University of Tennessee, Knoxville, TN 37996, USA*
[*]Correspondence: Yang Zhao, yzhao@utk.edu

Abstract

The effects of reduced growth rate on welfare and behavior in the same broiler strain have never been scientifically studied. This study evaluated the welfare and behaviors of Cobb 700 broilers as affected by growth rate (GR) and stocking density (SD). Slow-growing (GR < 50 g/day) and medium-growing (GR = 50 - 60 g/day) broilers were produced via providing 60% and 80% of the feed intake recommended in the Cobb 700 production manual for standard broilers (GR > 60 g/day). The broilers at all three GRs were reared at two stocking densities of 30 and 40 kg/m². Broiler feather coverage were evaluated when birds reached 1, 2 and 3 kg of body weights. Activity index was determined by top cameras and image processing, and feeding hours were recorded using the radio-frequency identification (RFID) systems. It held 45 days for standard, 52 days for medium-growing, and 62 days for slow-growing broilers to reach 3 kg market body weight. Feed conversion ratios (FCR, kg feed per kg weight gain) were 1.80 for slow-growing, 1.67 for medium-growing and 1.57 for standard broilers. Slow-growing broilers were more active and had better feather coverage, yet standard broilers showed best production performance. In conclusion, lowered GR and SD may improve certain broiler welfare conditions at a high expense of compromised production performance and prolonged production cycle.

Keywords: broiler, growth rate, stocking density, welfare, behavior, PLF technology

Introduction

The U.S. broiler industry has been the most productive animal industry by weight in the last two decades (USDA-NASS, 2020) and is leads the world in broiler production. However, public concerns on broiler welfare continue to grow. There are claims that slow-growing broilers have better locomotor ability and feather coverage than standard strains (Abeyesinghe et al., 2021, Bizeray et al., 2000). Such claims are based on references that compare different growth strains. However, advantages exhibited by the slow-growing strains can be attributed to the genetic discrepancy rather than growth rate. Impacts of growth rate on welfare and behavior have never been scientifically evaluated for the same strain of broilers. In addition, stocking density (SD) is a confounder because the slow-growing strains are usually reared at lower SDs than their counterparts.

Stocking density is directly related to the profitability and therefore has critical implications for the broiler industry. Current recommendations on densities vary. The National Chicken Council (NCC) recommends a stocking density of 32 - 44 kg/m², while Global Animal Partnership recommends lower stocking densities (27 - 29 kg/m²). Clearly, there is a huge discrepancy between the broiler industry and various animal welfare group standards.

Although easy to operate, manually assessing poultry behavior and welfare is subjective, less repeatable, time and labor intensive. Therefore, precision agriculture technologies have been increasingly considered and used for objective and automatic measurements. RFID technology, as reported, has been successfully used to measure behaviors of broilers (Li et al., 2019, Li et al., 2020, van der Sluis et al., 2020). Image processing technology has demonstrated abilities to evaluate broilers' activity level (Yang et al., 2020), and assess feather coverage of broilers (Cangar et al., 2008) combined with thermography technology.

The objective of this study was to evaluate the interaction of bird's welfare and behavior with growth rate and stocking density within the same commercial broiler strain using animal-based measures.

Materials and methods

Birds, diets, and management

A total of 267 Cobb 700 straight run broilers were used in this study, of which 252 birds were randomly placed in 18 pens while 15 birds were used as mortality replacements. Each pen had 1.5 m^2 of available space and was equipped with one 36-cm-diameter tube feeder and two nipple drinkers. Reducing the growth rate of broilers was achieved by restricted feeding. Feeds were provided ad libitum from Day 1 to Day 14 for all growth rate groups and rationed from Day 15 on for medium and slow-growing groups. There were three growth rates (< 50 g/day for slow growing, restricted feed intake to 60%; 50 - 60 g/day for medium growing, restricted feed intake to 80%; and > 60 g/day for standard broilers, ad libitum feeding) and two stocking densities (30 kg/m^2, 12 birds/pen; and 40 kg/m^2, 16 birds/pen), yielding six treatments combination with three replications per treatment combination. The broilers were assigned in 1:1 (male: female) ratio to each experimental pen. Light intensity, temperature, and humidity were adjusted according to commercial recommendations at bird age. Total bird weight in each experimental pen was determined twice a week. The feed consumption was measured every week for calculating weekly feed conversion ratio. All broilers were kept until their body weights reached 3 kg. The experiments followed the Guide for the Care and Use of Agriculture Animals in Research and Teaching (Federation of Animal Science Societies, 2010) and the University of Tennessee Institution Animal Care and Use Committee (IACUC Protocol #2847 - 0821).

Feather coverage

When broilers reached 1 kg, 2 kg, and 3 kg of body weight, five birds per pen were randomly selected for feather coverage measurement. Thermal camera (T865, Teledyne FLIR, Wilsonville, OR) was used to measure back and belly surface temperature of the broilers to determine the overall feather coverage. For each treatment group, a temperature threshold between feather and bare skin was determined to calculate the bare skin percentage.

Feeding behavior

The UHF - RFID antenna panels (Impinj Mini-guardrail and Times-7 A6034, TransTech System Inc., Aurora, OR) were placed under the feeder and connected to the RFID reader for evaluating bird utilization of feeders. From 21 days old to the end of the flock, small RFID tags (Atlas RFID Solutions LLC, Birmingham, AL) were attached to their necks of three broilers in each pen. Tags were adjusted daily. When the tagged broiler came to the feeder and bowed its head to feed, the RFID system detected the feeding behavior of the broilers and converted this into real time data. In this study, when the interval between two data points was less than 20 seconds, it was considered a continuous feeding behavior (Li et al., 2019).

Activity index

Activity index was measured by top-view cameras installed over each pen. High - performance security cameras (IP5M - B1186EB - 28MM, Amcrest Technologies, Houston, TX) were installed approximately 2 meters above each pen to monitor broilers' activities. Each top-view camera can cover two pens. The camera recorded videos in the first 15 minutes in each hour from the start of the experiment to the end of the experiment. Images were extracted from the videos every 0.2 seconds to analyze the activity index of broilers (Yang et al., 2020). The activity index is equal to the area of the non-overlapping part before and after the broiler movement (displacement area) divided by the area of the broiler (Bloemen et al., 1997).

Results

Production performance

The average growth rate of slow-growing, medium-growing and standard broilers were 48, 58 and 66 g/day respectively. The body weight and feed intake of the standard broilers were close to the Cobb (2020) commercial goal throughout the period (See Figure). Due to the feed ration, the medium-growing and slow-growing broilers in both stocking densities grew slower and consumed more feed to reach 3 kg target weight compared to the standard birds ($P < 0.01$).

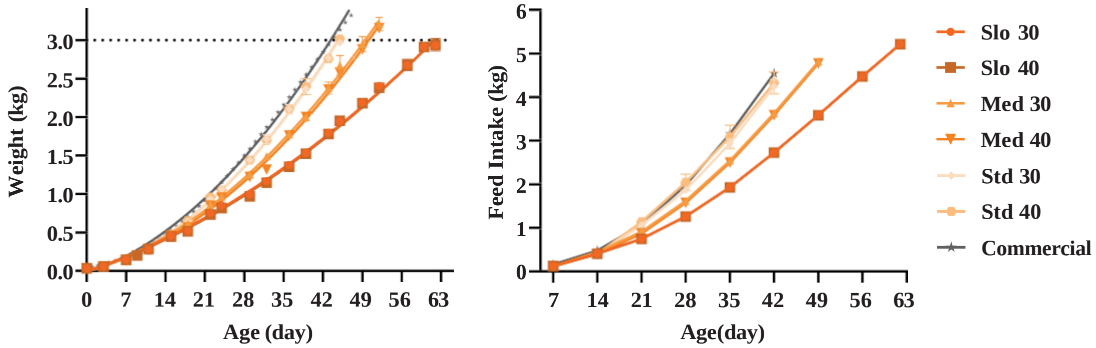

Figure 1: Body weights of slow-growing, medium-growing, and standard broilers reared at two stocking densities (30 and 40 kg/m²). Bird body weights described in the commercial manual (Cobb, 2020) was also included.

Table 1: Final feed conversion ratio (FCR) and days to reach 1, 2 and 3 kg body weight for slow-growing, medium-growing, and standard broilers reared at two stocking densities (30 and 40 kg/m²).

Target body weight	Slow		Medium		Standard	
	SD 30	SD 40	SD 30	SD 40	SD 30	SD 40
1 kg	28 d	28 d	25 d	25 d	23 d	23 d
2 kg	47 d	47 d	39 d	39 d	36 d	36 d
3 kg	62 d	62 d	52 d	52 d	45 d	45 d
Final FCR	1.80	1.80	1.65	1.68	1.55	1.59

As present in Table , the final FCRs of slow-growing, medium-growing and standard broilers were 1.57, 1.67, and 1.80 respectively ($P < 0.01$). Stocking density had no significant effect on the growth rate, feed intake and FCR ($P = 0.48$, 0.84 and 0.48 respectively). For the same growth rate, broilers in the difference of stocking densities reached 1, 2, 3 kg at the same age.

The effect of GR, weight and SD on body temperature, bare skin ratio, activity index and feeding hours.

The results present in Table showed that reducing the GR increases feather coverage and activity index. The average entire body temperature and bare skin ratio of the back and belly of broilers in the slow-growing group were significantly lower than those in medium-growing and standard broilers. The average body temperature of the slow-growing birds dropped by one degree compared to the other two groups, and the average bare skin ratio of the back was 1.6% lower than that of the standard one. Standard broilers had the lowest belly feather coverage, with 3.8% more exposed skin area than the other two groups. The ability index increased significantly when we reduced the growth rate of broilers. The average activity index of slow-growing and medium-growing birds were 53.0% and 87.0% higher than standard broilers, respectively. The medium-growing broilers spent 4.61 hours on feeding every day, while the slow-growing birds spent 3.47 hours on feeding, which was significantly lower than the medium-growing group.

Table 2: Effects of growth rate (GR), weight and stocking density (SD) on back and belly body temperature, bare skin ratio, activity index and feeding hours.

Measurement Items	Treatment				Std Error	*P* - value
	GR	Slow	Medium	Standard		
Back temperature (℃)		24.74^{B}	25.84^{A}	26.10^{A}	0.08	< 0.01
Belly temperature (℃)		26.51^{B}	27.78^{A}	27.85^{A}	0.08	< 0.01
Back skin ratio (%)		1.89^{B}	3.76^{A}	3.16^{A}	0.29	< 0.01
Belly skin ratio (%)		6.10^{B}	7.26^{B}	10.47^{A}	0.38	< 0.01
Activity index		0.028^{A}	0.023^{B}	0.015^{C}	< 0.01	< 0.01
Feeding hours (hr)		3.47^{b}	4.61^{a}	3.82^{ab}	0.27	0.01
	Weight	1 kg	2 kg	3 kg		
Back temperature (℃)		29.57^{A}	24.31^{B}	22.80^{C}	0.08	< 0.01
Belly temperature (℃)		30.59^{A}	26.40^{B}	25.15^{C}	0.08	< 0.01
Back skin ratio (%)		5.93^{A}	1.18^{B}	1.69^{B}	0.29	< 0.01
Belly skin ratio (%)		14.50^{A}	5.30^{B}	4.04^{B}	0.38	< 0.01
Activity index		0.031^{A}	0.018^{B}	0.017^{B}	< 0.01	< 0.01
Feeding hours		4.66^{A}	3.87^{AB}	3.36^{B}	0.27	< 0.01
	SD	30		40		
Back temperature (℃)		25.49		25.64	0.06	0.09
Belly temperature (℃)		27.33		27.43	0.06	0.27
Back skin ratio (%)		3.05		2.82	0.24	0.50
Belly skin ratio (%)		7.75		8.13	0.31	0.39
Activity index		0.022		0.022	< 0.01	0.84
Feeding hours (hr)		3.79		4.15	0.21	0.24

Regarding the effect of body weight, the bare skin ratio of broilers at 1 kg was significantly higher compared to when they were heavier, with about four and ten percent higher on back and belly bare skin ratio respectively. The average body surface temperature decreased gradually with the growth of broilers and the improvement of feather coverage. The surface temperature of the back and belly of broilers dropped by seven and five degrees respectively when their body weight increased from one to three kg. Chickens were most active at one kg, and when they grew to three kg, their activity index significantly decreased to 55.0% of their activity level when they were young. The feeding hours of broilers decreased as they gain weight, their average feeding hour at the end of trail were 1.3 hours less than that when they were young.

As for stocking density, there was no significant effect on feather coverage, body temperature, activity index and feeding hours of broilers.

Discussion

Effects of growth rate on broiler production performance

Feed restriction in the field, was used to manipulate chicken's growth and reduce metabolic diseases caused by rapid growth (Sahraei, 2014). Reducing the growth rate of the Cobb 700 commercial broiler strain birds by restricting feeding was demonstrated to be a feasible approach to slowing the growth rate of broilers in this study. Our results showed that limiting broiler feed intake from ad libitum (100%) to 80% and 60% from day 15 to the end of trial in the medium-growing and slow-growing groups reduced the average daily gain of broilers from 66 g/d, respectively to 58 and 48 g/d. Feed restriction slowed the growth rate of birds, impaired FCR, and increased activity levels. Restricted feeding to 80% (medium-growing) and 60% (slow-growing) both resulted in broilers consumed all the feed offered before the end of the day. Furthermore, limiting feeding to 60% causes birds to be hungry most of the day (Nielsen et al., 2003). Slowing down the growth rate of broilers compromised FCR, mainly due to the fact that the energy intake from the food, after digestion and metabolism, was the first mechanism used to support the animal's basal metabolic function to keep it alive, and the rest goes into body tissues or secretions (Zuidhof, 2019). The maintenance net energy of fast-growing strain broilers was determined to be 404 kJ/kg$^{\wedge 0.75}$ (Liu et al., 2017), which was the energy that broilers must allocate to the body every day. Decreasing the growth rate of broilers prolongs the feeding period and increasing the proportion of energy required for maintenance, which in turn reduced overall production efficiency.

Effects of stocking density on broiler production performance

Stocking density had no significant effect on average weight gain, feed intake and overall FCR. However, increasing the stocking density still influenced the slow-growing group, because we found that the male broilers in the slow-growing-SD-40 group weighed significantly more than the females when the average broiler weight was three kg (data not presented due to page limitation. Typically, males have higher final body weight and lower FCR than females (Trocino et al., 2020). With limited feed and feeding area, increasing stocking density can make broilers very crowded when feeding, especially as broilers become larger and heavier. Males preoccupied feeders and crowded out relatively weak females, and this effect was reinforced by the prolonged feeding period caused by restricted feeding.

Effects of growth rate on broiler feather coverage

Feathers are unique to birds, and their delicate microstructure helps to form a barrier that provides an insulating layer for birds to trap warm air and protect birds from external mechanical damage (Lingham, 2017). Body surface temperature can be used as an indicator for evaluating feather coverage (Zhao et al., 2013). The body surface temperature covered by feathers is significantly lower than that of bare skin. In our experiment, the average surface temperature and bare skin ratio of belly and back in the slow-growing group were significantly lower than those in the medium-growing and standard broilers due to their relatively longer time to reach 2 and 3 kg body weight for feather to growth. Slow-growing broilers took 20 days to grow from 1 and 2 kg, but feather growth was not as good as medium-growing and standard broilers, indicating that restricted feeding significantly reduced feather growth after 1 kg of broilers.

Effects of growth rate on broiler behavior

Decreasing growth rate could increase the activity level of broilers. Similar conclusions were also been reported in slow-growing broiler strains (Abeyesinghe et al., 2021, Rayner et al., 2020) or in restricted feeding studies (Trocino et al., 2020, Yan et al., 2021). Standard birds prefer to lie down, while medium-growing and slow-growing broilers might be driven by hunger to forage and thus displayed more motor behaviors. In addition, slow-growing broilers have a smaller weight-to-age ratio and were therefore more active. Standard broilers spent an average of 3.82 hours per day on feeding, and there were no significant differences between ages. The average daily feeding time of the medium-growing group was 4.61 hours, which was significantly higher than that of the slow-growing group by about 1.1 hours per day. Medium-growing birds spent about 5 hours per day around the feeder at one and two kg, then dropped to 3.9 hours per day at three kg. The slow-growing group was quite different. Due to hunger at one kg, they spent 5.24 hours around the feeder, even if the food in the feeder had been eaten, and then the feeding time dropped sharply to 3.0 and 2.2 at two and three kg, respectively. The birds already realized and were accustomed to having so little food each day that they prefer to lie still or move around in other areas after the limited food has been eaten.

Conclusions

Effects of growth rate and stocking density on broiler welfare and behaviors were researched with the help of PLF technologies. The results showed that feed restriction was slow the growth rate of birds. It held 45 days for standard, 52 days for medium-growing, and 62 days for slow-growing broilers to reach three kg body weight. Feed conversion ratios were 1.57, 1.67, and 1.80, respectively. Slow-growing broilers were more active and had better feather coverage. Medium-growing broilers spent the most time on feeding among the three growth groups, while standard broilers showed best production performance. In conclusion, lowered GR improved broiler feather coverage and activity index at a high expense of compromised production performance and prolonged production cycle.

Acknowledgments

Financial support of this research was provided by the US Poultry & Egg Association. The authors highly appreciate the assistance provided by staff and students at UT Animal Science Department, East Tennessee AgResearch and Education Center, USDA-ARS Poultry Research Unit, and Agricultural and Biological Engineering Department and Poultry Science Department at Mississippi State University.

References

Abeyesinghe, S.M., Chancellor, N.M., Hernandez, M.D., Chang, Y.M., Pearce, J., Demmers, T., and Nicol, C.J. (2021) Associations between behaviour and health outcomes in conventional and slow-growing breeds of broiler chicken. *Animal* 15(7), 100261.

Bizeray, D., Leterrier, C., Constantin, P., Picard, M., and Faure, J.M. (2000) Early locomotor behaviour in genetic stocks of chickens with different growth rates. *Applied Animal Behaviour Science* 68(3), 231-242.

Bloemen, H., Aerts, J.M., Berckmans, D., and Goedseels, V. (1997) Image analysis to measure activity index of animals. *Equine Veterinary Journal* 29(S23), 16-19.

Cangar, O., Aerts, J.M., Buyse, J., and Berckmans, D. 2008. Quantification of the spatial distribution of surface temperatures of broilers. *Poultry Science* 87(12), 2493-2499.

Cobb. 2020. Cobb700 broiler performance & nutrition supplement.

Li, G., Zhao, Y., Hailey, R., Zhang, N., Liang, Y., and Purswell, J.L. (2019) An ultra-high frequency radio frequency identification system for studying individual feeding and drinking behaviors of group-housed broilers. *Animal* 13(9), 2060-2069.

Li, N., Ren, Z., Li, D., and Zeng, L. (2020) Review: Automated techniques for monitoring the behaviour and welfare of broilers and laying hens: towards the goal of precision livestock farming. *Animal* 14(3), 617-625.

Lingham, S.T. (2017) The feather, a triumph of natural engineering and multifunctionality. 3-11 *in Proc. 32nd Poultry Science Symposium on Poultry Feathers and Skin - The Poultry Integument in Health and Welfare.* Cabi Publishing-C a B Int, Cambridge, ENGLAND.

Liu, W., Lin, C.H., Wu, Z.K., Liu, G.H., Yan, H.J., Yang, H.M., and Cai, H.Y. (2017) Estimation of the net energy requirement for maintenance in broilers. *Asian-Australasian Journal of Animal Sciences* 30(6), 849-856.

Nielsen, B.L., Litherland, M., and Noddegaard, F. (2003) Effects of qualitative and quantitative feed restriction on the activity of broiler chickens. *Applied Animal Behaviour Science* 83(4), 309-323.

Rayner, A.C., Newberry, R.C., Vas, J., and Mullan, S. (2020) Slow-growing broilers are healthier and express more behavioural indicators of positive welfare. *Scientific Reports* 10(1), 15151.

Sahraei, M. (2014) Effects of feed restriction on metabolic disorders in broiler chickens: A review. *Biotechnology in Animal Husbandry* 30(1), 1-13.

Trocino, A., White, P., Bordignon, F., Ferrante, V., Bertotto, D., Birolo, M., Pillan, G., and Xiccato, G. (2020) Effect of feed restriction on the behaviour and welfare of broiler chickens. *Animals (Basel)* 10(5).

USDA-NASS. (2020) *Meat animals: production by year*, US.

van der Sluis, M., de Haas, Y., de Klerk, B., Rodenburg, T.B., and Ellen, E.D. (2020) Assessing the activity of individual group-housed broilers throughout life using a passive radio frequency identification system-a validation study. Sensors 20(13), 20.

Yan, C., Xiao, J., Chen, D., Turner, S.P., Li, Z., Liu, H., Liu, W., Liu, J., Chen, S., and Zhao, X. (2021) Feed restriction induced changes in behavior, corticosterone, and microbial programming in slow- and fast-growing chicken breeds. *Animals (Basel)* 11(1).

Yang, X., Zhao, Y., and Tabler, G.T. (2020) Accuracy of broiler activity index as affected by sampling time interval. *Animals* (Basel) 10(6).

Zhao, Y., Xin, H., and Dong, B. (2013) Use of infrared thermography to assess laying-hen feather coverage. *Poultry Science* 92(2), 295-302.

Zuidhof, M.J. (2019) A review of dietary metabolizable and net energy: uncoupling heat production and retained energy. *Journal of Applied Poultry Research* 28(2), 231-241.