Tropical Animal Health and Production (2021) 53: 461
https://doi.org/10.1007/s11250-021-02890-1

REGULAR ARTICLES

Effect of different feed restriction regimens on performance, behaviors, blood cortisol, and carcass parameters of growing Sasso broilers

Esraa Shusha[1] · Souad Ahmed[1] · Essam Ali[1] · Ahmed Sabek[1]

Received: 17 June 2021 / Accepted: 10 September 2021 / Published online: 20 September 2021
© The Author(s), under exclusive licence to Springer Nature B.V. 2021

Abstract
The aim of this study was to evaluate the effect of different feed restriction regimens on performance, behavioral patterns, blood cortisol, and carcass parameters in Sasso broilers. Sixty healthy 1-day-old unsexed Sasso chicks were randomly assigned to three groups (20 chicks per group) and each group was divided into 4 replicates with 5 chicks each based on feed restriction program during the rearing period (60 days). The first group (G1) is control in which birds were fed ad libitum had free access to feed (no restriction). The second group (G2) was subjected to temporary feed restriction at the first 2 weeks as birds had access to feed for 12 h only after that they had free access to feed until the end of the experimental period. The third one (G3) was subjected to continuous feed restriction as birds had free access to feed for 12 h only throughout the rearing periods. During the study period, growth performance and behavioral patterns were estimated. At the end of the study, blood samples for cortisol testing were taken. Three birds from each group were slaughtered at the end of the study to see how the feed restriction affected carcass parameters. Feed restriction had a substantial impact ($P \leq 0.05$) on final body weight and carcass parameters. Feed restriction elevated blood cortisol significantly ($P = 0.004$). Feed restriction showed a significant impact on some behaviors as feeding, stretching, preening, and aggression. Overall, different feed restriction programs had a wide effect on growth performance, behaviors, cortisol concentration, and carcass parameters of Sasso broilers.

Keywords Feed restriction time · Behavior · Growth performance · Cortisol · Carcass parameters

Introduction

In developing countries, the poultry industry offers major economic, social, and cultural benefits, as well as playing an important role in family nutrition. The contribution of poultry in the world's total animal protein production is 40%. Broilers, like any other species, have basic needs to stay healthy. To express normal behavior, proper broiler management is needed. Broilers should be able to freely fly, peck, scratch, flap their wings, groom their feathers, rest, and sleep (Dawkins 2003). Local breeds are closely linked to the environment and contribute to the maintenance of biodiversity and successful agricultural production, particularly in deprived areas, so using them as an alternative system in the poultry industry has significant advantages (Franco et al. 2012). Fast-growing poultry with high feed conversion rates have had negative consequences for health, meat quality, and welfare (da Silva et al. 2017; Hartcher and Lum 2020), slower-growing broilers in comparison to fast-growing meat poultry hybrids are thought to suffer from less physical weaknesses and health issues (Bergmann et al. 2017).

Feed restriction (FR) is one of many factors that affect broiler welfare by inducing stress, which is manifested as an increase in plasma corticosterone (Hocking et al. 1996, 1997; De Jong et al. 2002). Some quantitative or qualitative approaches may be used to apply FR. Quantitative FR refers to reducing the amount of nutritious feed provided; qualitative feed restriction, on the other hand, is achieved by lowering the energy content in a given amount of feed (Sandilands et al. 2006). In this way, the amount of feed provided can be increased without increasing total energy (Savory et al. 1996; Nielsen et al. 2011). Birds may eat the

✉ Ahmed Sabek
ahmedsabek1987@gmail.com

[1] Department of Veterinary Hygiene and Management, Faculty of Veterinary Medicine, Benha University, Benha, Egypt

same amount of food despite being restricted at feeding time (Azis et al. 2019).

The benefits of feed restriction in broilers include avoiding rapid growth and problems such as poor reproductive performance, lameness, ascites, and mortality (Mench 2002; Tolkamp et al. 2005), while the disadvantages include feeling hungry and changes in normal chicken behaviors such as increased aggression, pecking the feeders, drinkers and litter, running, and over-drinking (Hocking et al. 1997). In fact, FR increases crop size and storage capacity (Svihus et al. 2013), as well as changing bird feeding habits, resulting in an increase in feed intake (FI) just before the feed deprivation phase begins (Shynkaruk et al. 2019). There have been few previous studies and reports on the effect of feed restriction especially period of restriction (restriction time) on Sasso broilers. Hence, this study was conducted to assess the effect of different feed restriction routines on growth performance, blood cortisol, carcass parameters, and a wide range of behaviors of Sasso broilers.

Materials and methods

The research procedures were carried out in accordance with the standards for the treatment and use of animals at Benha University's College of Veterinary Medicine.

Birds and management

A total of 60 healthy unsexed 1-day-old Sasso chicks with an average body weight of 37 ± 2.12 g were purchased from a private farm in Kalyobiya province, Egypt. The chicks were housed in 3 symmetrical pens, each with a surface area of about 2 m^2. The chicks were received at a house that had been previously prepared; the floor had been covered with a layer of wood shaving (10 cm) and the pens had been warmed to 33 °C, then gradually decreased to 30 °C, with relative humidity ranging from 50 to 70% during the experimental phase. Trough feeders and handbell drinkers were used to provide feed and water 24 h before the chicks arrived. From 1 to 21 days old, a starter diet (23% CP and 2988 kcal/kg ME) was given, followed by a grower diet (21% CP and 3083 kcal/kg ME) from 22 to 42 days old, and finally a finisher diet (19% CP and 3200 kcal/kg ME) from 43 to 60 days old. The content of the diet is shown in Table 1.

Experimental design

The chicks were allocated randomly to three groups (20 chicks each) and each group was divided into 4 replicates with 5 chicks each based on feed restriction program during the rearing period (60 days), the chicks were identified using a permanent color marker. The first group (G1) had free access to feed for 24 h throughout the rearing period (no restriction). The second group (G2) was subjected to temporary feed restriction within the first 2 weeks of rearing period in which birds had access to feed for 12 h only from 8.00 am to 8.00 pm then the feeders were removed from the pen until the next day. After 2 weeks, the birds had free access to feed for 24 h until the end of the experimental period. The third one (G3) was subjected to continuous feed restriction as birds were fed for 12 h only from 8.00 am to 8.00 pm throughout the rearing period.

Table 1 The content of diets

Nutrient	Starter (1–21 days)	Grower (22–42 days)	Finisher (43–60 days)
Metabolizable energy (kcal/kg)	2988	3083	3200
Crude protein%	23	21	19
Calcium%	1.1	1.2	1.2
Phosphorus%	0.45	0.5	0.5
Crude fat%	3.5	4	4
Lysine%	1.25	1.20	1.15
Methionine%	0.55	0.5	0.5

Growth performance parameters

The average body weight was recorded at the beginning of the study. To check the effect of treatments on birds' body weight, birds were weighed every 2 weeks until the end of the study using a digital balance.

Behavioral observation

Behavioral patterns were recorded 3 times per week. Each group was observed for 1 day weekly, 3 times per day at 8.00–9.00 am, 12.00–1.00 noon, and 5.00–6.00 pm. Each bird's behavioral patterns frequency was observed by focal observation for 3 min with a total time of observation of 9 min. All observations were carried out by one observer who was present at all measurement points in the experiment. As feed restriction mainly affected the ingestive behavior and welfare-related behaviors. The most recorded behaviors were feeding, drinking, resting, stretching, preening, and aggression as shown in Table 2.

Blood sampling and hormonal analysis

To check the effect of feed restriction on blood hormones, at the end of the study, three birds from each group were selected at random for blood samples to test cortisol as a stress indicator. 3 mL of blood from each bird was collected

Table 2 Description of behavioral patterns

Behavior	Description
Feeding	Bird putting its beak inside the feeder, pecking, and ingestion of food after its provision
Drinking	Bird touching the drinker with its beak and raising its head
Resting	Lying or sitting down
Stretching	Wing or leg stretch
Preening	Bird is using its beak to clean its feather
Aggression	Birds pecking each other

from the wing vein between 9.00 and 10.00 am in a clean sterilized labeled tube and centrifuged at 3000 rpm for 10 min. The serum was separated and kept at − 20 °C until analysis by ELISA using (Cortisol II, cobas®) kits.

Slaughtering and carcass parameters

At the end of the study, three birds from each group were randomly chosen, weighted, and slaughtered. The slaughtered birds were immersed in hot water to facilitate feather removal; feathers were removed manually. The head, neck, legs, and wings were removed. The internal organs and fat were removed; the rest of the body was defined as carcass. Crop, gizzard, and intestine were evacuated. The carcass weight was recorded also internal organs (heart, lung, liver, spleen, crop, gizzard, and intestine) and fat weights were measured.

Statistical analysis

The SPSS software version 22 was used to analyze the data. Growth performance, cortisol concentration, and carcass parameters data were analyzed using analysis of variance (Anova). There was no effect of day times on behaviors so this factor was ignored. The normality of the data distribution was evaluated by a Shapiro–Wilk test.

Behavioral data was analyzed using analysis of variance (Anova). Means and standard error means were used to present the data. $P \leq 0.05$ was used to declare the data to be different.

Results

Growth performance

As expected, feed restriction significantly affected the body weight of broilers as group 3 in which birds were subjected to continuous restriction showed the lowest body weight during the different weeks of the study. Temporary feed restriction did not have any adverse effect on the body weight of birds in advanced age as birds showed the highest body weight from the 6th week until the end of the study followed by the control group and third group respectively (Table 3).

Behavioral patterns

Behavioral data as affected by feed restriction are shown in Table 4. The frequency of feeding behavior was higher in the continuous feed restriction group than in the other two groups ($P = 0.001$). In contrast, this group showed lower resting frequency than the second and control group respectively ($P = 0.02$). The high incidence of stretching was observed in group 2 followed by group 3 and control

Table 4 Behavioral patterns frequency of Sasso broilers as affected by feed restriction

Behavior frequency	Feed restriction			
	G1	G2	G3	*P* value
Feeding	1.76 ± 0.08^{ab}	1.63 ± 0.08^{b}	1.94 ± 0.07^{a}	0.001
Drinking	1.70 ± 0.07	1.60 ± 0.07	1.57 ± 0.07	0.4
Resting	1.40 ± 0.20^{a}	1.60 ± 0.17^{a}	1.00 ± 0.18^{b}	0.02
Stretching	1.25 ± 0.12^{b}	1.67 ± 0.10^{a}	1.36 ± 0.13^{ab}	0.002
Preening	1.55 ± 0.24^{b}	2.10 ± 0.21^{ab}	2.32 ± 0.21^{a}	0.01
Aggression	1.00 ± 0.30^{c}	2.33 ± 0.23^{a}	1.37 ± 0.19^{bc}	< 0.001

Least square means (± SE) with different superscript letters in the same row are significantly different at $P \leq 0.05$

Table 3 Body weight of Sasso broilers as affected by feed restriction

Body weight (g)	Feed restriction			
	G1	G2	G3	*P* value
BW0	39.50 ± 2.00	36.00 ± 2.00	35.00 ± 2.00	0.3
BW2	230.50 ± 12.04	206.00 ± 12.04	194.00 ± 12.04	0.1
BW4	781.00 ± 47.77^{a}	706.00 ± 47.77^{ab}	608.50 ± 47.77^{b}	0.05
BW6	1335 ± 72.96^{a}	1519 ± 72.96^{a}	1048 ± 72.96^{b}	< 0.001
BW8	2093 ± 151.15^{a}	2138 ± 151.15^{a}	1424 ± 151.15^{b}	0.004

Least square means (± SE) with different superscript letters in the same row are significantly different at $P \leq 0.05$

one ($P=0.002$), while birds in group 3 showed the highest incidence of preening. Feed restriction significantly affected aggression as the highest frequency of aggression was recorded in group 2 which was subjected to temporary feed restriction than the continuous feed restriction group while the lowest frequency was observed in the control group ($P<0.001$). Feed restriction had no significant effect on the drinking behavior of broilers.

Cortisol concentration

Feed restriction affected significantly blood cortisol concentration at the end of the trial as the average cortisol concentration was 0.20 ± 0.01, 0.25 ± 0.01, and 0.29 ± 0.01 µg/dL for the first, second, and third group respectively ($P=0.004$) (Table 5).

Carcass parameters

Compared to control and temporary feed restriction groups, the third group in which birds were subjected to continuous feed restriction showed the lowest slaughter, carcass, organs, and fat weight (Table 6).

Discussion

Growth performance

It was clear that there was a significant effect of continuous feed restriction in the body weight of birds as birds which subjected to feed restriction throughout the study period showed the lowest body weight unlike birds which subjected to early feed restriction for 2 weeks recorded the highest final body weight. The negative effect of continuous feed restriction on body weight may be attributed to the reduction of feed intake when feed supply was limited during the restricted time. The current result agrees with (Azis et al. 2019) who recorded the same effect of feed restriction on Lohmann broilers as broilers that had a free access to feed for 12 h daily for 35 days showed the lowest body weight comparing to other groups. Cobb broilers body weight was reduced as a result of feed restriction both in terms of quantity and time (Butzen et al. 2013). In the same line to the current findings, meal-time feeding restriction for 45 days in Ross-308 chicks resulted in lower final body weight than the control group fed ad libitum (Konca et al. 2008). In contrast, birds subjected to feed restriction in the age between 4 and 11 days showed the lowest final body weight (Acar et al. 1995).

Behavioral patterns

The frequency of feeding behavior was higher in the continuous feed-restricted group than the other two groups. This may be attributed to feed-restricted birds which learn to adjust their feeding habits by increasing feed intake frequency because of feed restriction adaptation. Broilers will be able to forecast when a feed deficit will occur (Fondevila et al. 2020). The same findings of feed restriction effect of feeding behaviors of broilers were observed by (Aranibar et al. 2020; Trocino et al. 2020; Yan et al. 2021). The control group had the highest incidence of drinking behavior, followed by the temporary feed-restricted group, and then the continuous feed limited group, albeit this difference was not significant because the water was always available to all three groups. Unlike Yan et al. (2021) who recorded a higher frequency of drinking behavior in feed-restricted birds ($P<0.05$). Resting or lying down was affected significantly by feed restriction as the lowest frequency of lying was recorded in continuously

Table 5 Effect of feed restriction on blood Cortisol of Sasso broilers

Hormone	Feed restriction			
	G1	G2	G3	*P* value
Cortisol (µg/dL)	0.20 ± 0.01^{b}	0.25 ± 0.01^{ab}	0.29 ± 0.01^{a}	0.004

Least square means (±SE) with different superscript letters in the same row are significantly different at $P\leq0.05$

Table 6 Effect of feed restriction on carcass parameters of Sasso broilers

Carcass parameters	Feed restriction			
	G1	G2	G3	*P* value
Slaughter weight (g)	2503 ± 167.05^{a}	2593 ± 167.05^{a}	1437 ± 167.05^{b}	0.005
Carcass weight (g)	2253 ± 167.05^{a}	2343 ± 167.05^{a}	1187 ± 167.05^{b}	0.005
Organ's weight (heart, lung, liver, spleen, crop, gizzard, and intestine) (g)	350.33 ± 25.58^{a}	346.66 ± 25.58^{a}	190.33 ± 25.58^{b}	0.007
Fat weight (g)	325.33 ± 21.18^{a}	358.60 ± 21.18^{a}	130.33 ± 21.18^{b}	0.001

Least square means (±SE) with different superscript letters in the same row are significantly different at $P\leq0.05$

feed-restricted birds as they consumed more time in feeding and exploration activity; hence, the frequency of resting was low. The current findings are in the same line with the observations of Trocino et al. (2020) and Yan et al. (2021). Comfort behaviors like stretching and preening were affected by feed restriction as the highest incidence of stretching were observed in temporarily restricted birds followed by continuously restricted birds then the control birds; meanwhile, the continuously restricted birds showed the highest frequency of preening; these results propose that birds adapted to the feeding routine with time. The results agree with Aranibar et al. (2020). In contrast, Trocino et al. (2020) reported the reduction in comfort behaviors of birds as affected by feed restriction. A previous study by Yan et al. (2021) showed that there was no effect of feed restriction on the comforting activity of birds ($P > 0.05$). Birds which restricted for 2 weeks showed a higher frequency of aggression than continuously restricted birds and birds fed ad libitum, respectively. This result may be attributed to the fighting actions that occurred around the feeders in the restricted groups because of overcrowding; these findings are contrary to Trocino et al. (2020) who stated that when birds were restricted, they did not show any aggressive behavior between each other.

Cortisol concentration

At the end of the study, it was clear that cortisol concentration was significantly affected by feed restriction. The increase of blood cortisol in feed-restricted birds may be attributed to the persistent feeling of stress due to feed shortage. However, this result was preliminary as the number of samples was small and, in the future, work these findings will be confirmed by using a wide range of samples. One of the stress factors that affect plasma biochemical parameters is dietary restriction. Stress and welfare status of birds can be evaluated by many indicators; corticosterone is one of them. Previous work on quantitative feed restriction in birds revealed the same results as the current work concerning feed restriction time. Corticosterone in feces of feed-restricted birds was higher than ad libitum birds (13.6 vs. 12.2 ng/g) (Trocino et al. 2020); the same effect of feed restriction was reported by Yan et al. (2021). Quantitative feed restriction causes symptoms of stress, such as elevated plasma corticosterone levels in broiler chickens (Hocking et al. 1996; Savory et al. 1996; Rajman et al. 2006). The current study revealed that as the feed restriction time increased cortisol level elevated in the blood. The current result agrees with Sherif and Mansour (2019) who found that with restricted feed intake of Cobb-500 broilers at levels of 20, 25, 30, 35, and 40%, the corticosterone concentration increased compared to birds fed on basal diet. Unlike the current result, ad libitum fed birds showed a higher plasma corticosterone concentration than early-age feed-restricted birds as reported by Al-Aqil et al. (2009).

Carcass parameters

The findings of the current study clearly indicate that continuous feed restriction routine affected significantly carcass parameters included slaughter, carcass, organs, and fat weight. Sasso broilers subjected to continuous feed restriction showed the lowest carcass parameters comparing to other treatments; this finding of carcass parameters is correlated with the effect of continuous feed restriction on the final body weight of birds. As a result of feed restriction, the fat content was reduced due to fat mobilization for energy supply and by increasing the duration of feed restriction, the fat content of the carcass decreased (Omosebi et al. 2014). In the same line with the present study, Saleh et al. (2005) discovered that feed restriction decreased the carcass percent of broilers significantly. Furthermore, feed-restricted broilers had much lower heart weight than those on a normal diet (Onbaşılar et al. 2009). Lower carcass fat content due to feed restriction was previously reported by Cabel and Waldroup (1990), unlike the current result, carcass composition did not change as affected by feed restriction (Summers et al. 1990; Jones and Farrell 1992; Bortoluzzi et al. 2013).

Conclusion

It is concluded that continuous feed restriction throughout the rearing period decreased the bodyweight of Sasso broilers with a chronic stress effect. Also, continuous feed restriction had an adverse effect on carcass parameters. Temporary feed restriction for 2 weeks at early life is recommended as it does not have any adverse effect on final body weight, resting, comfort behavior, and carcass parameters of growing Sasso broilers plus it saves the rearing cost of birds. In future work, more blood samples and more birds will be slaughtered; also, some health parameters like pododermatitis and hock burn will be estimated to confirm the effect of feed restriction on Sasso broilers.

Acknowledgements The authors are grateful to the College of Veterinary Medicine, Benha University which facilities carrying out this study. The authors thank Dr. Mahmoud Al Atrony from College of Agriculture, Benha University, for helping us in data analysis.

Author contribution Conceptualization, E.S.H., A.S., and S.A.; methodology, E.S.H.; investigation, E.S.H., and A.S.; detection and analysis, E.S.H.; validation, A.S., S.A., and E.A.; writing original draft, E.S.H.;

manuscript review, editing, and preparation for submission, A.S. supervision, S.A. and E.A.

Data availability Not applicable.

Code availability Not applicable.

Declarations

Ethics approval The research procedures were carried out in accordance with the standards for the treatment and use of animals at Benha University's College of Veterinary Medicine.

Consent to participate All authors agree to participate in the current work.

Consent for publication All authors agree to publish the findings of the current research.

Conflict of interest The authors declare no competing interests.

References

Acar, N., Sizemore, F.G., Leach, G.R., Wideman, R.F., Owen, R.L. and Barbato, G.F., 1995. Growth of broiler chickens in response to feed restriction regimens to reduce ascites. Poultry science, 74 (5), 833-843.

Al-Aqil, A., Zulkifli, I., Sazili, A.Q., Omar, A.R. and Rajion, M.A., 2009. The effects of the hot, humid tropical climate and early age feed restriction on stress and fear responses, and performance in broiler chickens. Asian-Australasian Journal of Animal Sciences, 22 (11), 1581- 1586.

Aranibar, C.D., Chen, C., Davis, A.J., Daley, W.I., Dunkley, C., Kim, W.K., Usher, C., Webster, A.B. and Wilson, J.L., 2020. Impact of an alternate feeding program on broiler breeder pullet behavior, performance, and plasma corticosterone. Poultry Science, 99 (2), 829-838.

Azis, A., Berliana, S. and . A., 2019. Effects of Feeding Time Restriction During the Whole Rearing Period on the Growth Performance of Broiler Chickens. International Journal of Poultry Science, 18 (1), 14-20.

Bergmann, S., Schwarzer, A., Wilutzky, K., Louton, H., Bachmeier, J., Schmidt, P., Erhard, M. and Rauch, E., 2017. Behavior as welfare indicator for the rearing of broilers in an enriched husbandry environment—A field study. Journal of Veterinary Behavior: Clinical Applications and Research, 19, 90-101.

Bortoluzzi, C., Fernandes, J.I.M., Contini, J.P., Gurski, T.J., Esser, A.F.G. and Prokoski, K., 2013. Quantitative feed restriction from 35 to 42 days of age for broiler chickens. Revista Brasileira de Saúde e Produção Animal, 14 (4), 778-784.

Butzen, F.M., Ribeiro, A.M.L., Vieira, M.M., Kessler, A.M., Dadalt, J.C. and Della, M.P., 2013. Early feed restriction in broilers. I-Performance, body fraction weights, and meat quality. Journal of Applied Poultry Research, 22 (2) , 251-259.

Cabel, M.C. and Waldroup, P.W., 1990. Effect of Different Nutrient-Restriction Programs Early in Life on Broiler Performance and Abdominal Fat Content. Poultry Science, 69 (4), 652-660.

da Silva, D.C.F., de Arruda, A.M.V. and Gonçalves, A.A., 2017. Quality characteristics of broiler chicken meat from free-range and industrial poultry system for the consumers. Journal of Food Science and Technology, 54 (7), 1818-1826.

Dawkins, M.S., 2003. Behaviour as a tool in the assessment of animal welfare. Zoology, 106 (4), 383-387.

De Jong, I.C., Van Voorst, S., Ehlhardt, D.A. and Blokhuis, H.J., 2002. Effects of restricted feeding on physiological stress parameters in growing broiler breeders. British Poultry Science, 43 (2), 157-168.

Fondevila, G., Archs, J.L., Cámara, L., de Juan, A.F. and Mateos, G.G., 2020. The length of the feed restriction period affects eating behavior, growth performance, and the development of the proximal part of the gastrointestinal tract of young broilers .Poultry Science, 99 (2), 1010-1018.

Franco, D., Rois, D., Vázquez, J.A., Purriños, L., González, R. and Lorenzo, J.M., 2012. Breed effect between Mos rooster (Galician indigenous breed) and Sasso T-44 line and finishing feed effect of commercial fodder or corn. Poultry Science, 91 (2), 487- 498.

Hartcher, K.M. and Lum, H.K., 2020. Genetic selection of broilers and welfare consequences: a review. World's Poultry Science Journal, 76 (1), 154-167.

Hocking, P.M., Maxwell, M.H. and Mitchell, M.A., 1996. Relationships between the degree of food restriction and welfare indices in broiler breeder females British Poultry Science, 37 (2), 263- 278.

Hocking, P.M., Hughes, B.O. and Keer-Keer, S., 1997. Comparison of food intake, rate of consumption, pecking activity and behaviour in layer and broiler breeder males. British Poultry Science, 38 (3), 237-240.

Jones, G.P.D. and Farrell, D.J., 1992. Early-life food restriction of broiler chickens i. methods of application, amino acid supplementation and the age at which restrictions should commence. British Poultry Science, 33 (3), 279-587.

Konca, Y., Yaylak, E. and Önenç, A., 2008. Effects of meal-time feeding and protein restriction on walking ability and some bone and carcass properties in broilers. Animal, 2 (9), 1324-1330.

Mench, J.A., 2002. Broiler breeders: Feed restriction and welfare. World´s Poultry Science Journal, 58 (1), 23- 29

Nielsen, B.L., Thodberg, K., Malmkvist, J. and Steenfeldt, S., 2011. Proportion of insoluble fibre in the diet affects behaviour and hunger in broiler breeders growing at similar rates. Animal, 5 (8), 1247-1258.

Omosebi, D.J., Adeyemi, O.A., Sogunle, M.O., Idowu, O.M.O. and Njoku, C.P., 2014. Effects of duration and level of feed restriction on performance and meat quality of broiler chickens. Archivos de Zootecnia, 63 (244), 611- 621.

Onbaşılar, E.E., Yalçın, S., Torlak, E. and Özdemir, P., 2009. Effects of early feed restriction on live performance, carcass characteristics, meat and liver composition, some blood parameters, heterophil-lymphocyte ratio, antibody production and tonic immobility duration. Tropical Animal Health and Production, 41 (7), 1513-1519.

Rajman, M., Juráni, M., Lamošová, D., Máčajová, M., Sedlačková, M., Košťál, Ľ., Ježová, D. and Výboh, P., 2006. The effects of feed restriction on plasma biochemistry in growing meat type chickens (Gallus gallus). Comparative Biochemistry and Physiology - A Molecular and Integrative Physiology, 145 (3), 363-371.

Saleh, E.A., Watkins, S.E., Waldroup, A.L. and Waldroup, P.W., 2005. Effects of early quantitative feed restriction on live performance and carcass composition of male broilers grown for further processing. Journal of Applied Poultry Research, 14 (1), 87-93.

Sandilands, V., Tolkamp, B.J., Savory, C.J. and Kyriazakis, I., 2006. Behaviour and welfare of broiler breeders fed qualitatively restricted diets during rearing: Are there viable alternatives to quantitative restriction?. Applied Animal Behaviour Science, 96 , 53- 67.

Savory, C.J., Hocking, P.M., Mann, J.S. and Maxwell, M.H., 1996. Is broiler breeder welfare improved by using qualitative rather than quantitative food restriction to limit growth rate?. Animal Welfare, 5 (2), 105-127.

Sherif, S.K., and Mansour, A.M., 2019. Effect of early feed restriction on broiler performance, blood and carcass parameters under summer conditions. Egyptian Journal of Nutrition and Feeds, 22, 155-165.

Shynkaruk, T., Classen, H.L., Crowe, T.G. and Schwean-Lardner, K., 2019. The impact of dark exposure on broiler feeding behavior and weight of gastrointestinal tract segments and contents. Poultry Science, 98 (6), 2448- 2458.

Summers, J.D., Spratt, D. and Atkinson, J.L., 1990. Restricted Feeding and Compensatory Growth for Broilers. Poultry Science, 69 (11), 1855-1861.

Svihus, B., Lund, V.B., Borjgen, B., Bedford, M.R. and Bakken, M., 2013. Effect of intermittent feeding, structural components and phytase on performance and behaviour of broiler chickens British Poultry Science, 54 (2), 222- 230.

Tolkamp, B.J., Sandilands, V. and Kyriazakis, I., 2005. Effects of qualitative feed restriction during rearing on the performance of broiler breeders during rearing and lay. Poultry Science, 84 (8), 1286-1293.

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, 10 (5), 830.

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, 11 (1), 1- 16.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.