Effects of Different Feed Restriction Methods on Growth Performance, Slaughter Performance, and Skeletal Traits of Arbor Acres Broilers: Postprint

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Abstract

This experiment aimed to investigate the effects of different feed restriction methods on the growth performance, slaughter performance, and bone traits of Arbor Acres (AA) broiler chickens. Eighty 7-day-old AA broiler chickens were selected and randomly divided into 4 groups: control group, feed quantity restriction group, energy restriction group, and protein restriction group, with 20 chickens per group. After 14 days of feed restriction (21 days of age) and 21 days of compensatory growth (42 days of age), 8 chickens from each group were slaughtered to collect and weigh tissues including breast muscle, leg muscle, abdominal fat, heart, liver, spleen, thymus, bursa of Fabricius, and bones, as well as to measure bone length and diameter. The results showed: 1) After feed restriction, the average daily gain of broilers in the three restriction groups was significantly lower than that in the control group ($P<0.05$). After compensatory growth, there were no significant differences in average daily feed intake, average daily gain, and feed conversion ratio among all groups ($P>0.05$), but the final body weight of the feed quantity restriction group was significantly lower than that of the control group ($P<0.05$). 2) After feed restriction, the eviscerated yield percentage, semi-eviscerated yield percentage, breast muscle percentage, leg muscle percentage, and abdominal fat percentage of broilers in the feed quantity restriction group were significantly lower than those in the control group ($P<0.05$), and the abdominal fat percentage of broilers in the feed quantity restriction group and energy restriction group was significantly lower than that in the protein restriction group and control group ($P<0.05$). After compensatory growth, there were no significant differences in breast muscle percentage and leg muscle percentage among all groups ($P>0.05$), but the abdominal fat percentage of broilers in the feed quantity restriction group was

significantly higher than that in the control group (P<0.05). 3) After feed restriction, the liver index of broilers in the protein restriction group was significantly higher than that in the other three groups (P<0.05), the pancreas index of broilers in the feed quantity restriction group was significantly higher than that in the other three groups (P<0.05), and the spleen index of the control group was significantly higher than that of the other three groups (P<0.05). After compensatory growth, there were no significant differences in heart index, liver index, pancreas index, spleen index, thymus index, and bursa of Fabricius index among all groups (P>0.05). 4) After feed restriction, the tibia weight, tibia length, tibia diameter, femur weight, and femur length of broilers in the feed quantity restriction group were significantly lower than those in the other three groups (P<0.05), and the femur diameter of broilers in the feed quantity restriction group and energy restriction group was significantly lower than that in the control group and protein restriction group (P<0.05). After compensatory growth, there were no significant differences in tibia weight, tibia length, tibia diameter, femur weight, femur length, and femur diameter among all groups (P>0.05). In conclusion, all three feed restriction methods reduced the average daily gain and some bone trait indicators of AA broiler chickens, with the feed quantity restriction group having the greatest impact on average daily gain and bone traits. After 21 days of compensatory growth, all three restriction groups exhibited compensatory growth effects, and there were no significant differences in bone traits between the three restriction groups and the control group; however, the feed quantity restriction method reduced the overall average daily gain and final body weight of broilers, thus caution is advised when using feed quantity restriction in production.

Full Text

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Abstract

This experiment was conducted to investigate the effects of different feed restriction methods on growth performance, slaughter performance, and skeletal traits of Arbor Acres (AA) broiler chickens. Eighty 7-day-old AA broilers were randomly assigned to four groups: a control group, a feed intake restriction group, an energy restriction group, and a protein restriction group, with 20 replicates per group. After 14 days of feed restriction (at 21 days of age) followed by 21 days of compensatory growth (at 42 days of age), eight chickens from each group were slaughtered to collect and weigh tissues including breast muscle, leg muscle, abdominal fat, heart, liver, spleen, thymus, bursa of Fabricius, and leg bones, as well as to measure bone length and diameter. The results showed: (1) After feed restriction, the average daily gain (ADG) of all three restriction groups was significantly lower than that of the control group ($P<0.05$). Following compensatory growth, no significant differences were observed among groups in average daily feed intake (ADFI), ADG, or feed-to-gain ratio (F/G) ($P>0.05$), although the final body weight of the feed intake restriction group remained significantly lower than the control group ($P<0.05$). (2) Post-restriction, the feed intake restriction group exhibited significantly lower eviscerated yield, semi-eviscerated yield, breast muscle percentage, leg muscle percentage, and abdominal fat percentage compared to the control group ($P<0.05$). Both the feed intake and energy restriction groups had significantly lower abdominal fat percentages than the protein restriction and control groups ($P<0.05$). After compensatory growth, no significant differences in breast or leg muscle percentages were detected among groups ($P>0.05$), though the abdominal fat percentage in the feed intake restriction group was significantly higher than in the control group ($P<0.05$). (3) Following restriction, the protein restriction group showed a significantly higher liver index than the other three groups ($P<0.05$), while the feed intake restriction group had a significantly higher pancreas index ($P<0.05$) and the control group displayed a significantly higher spleen index ($P<0.05$). After compensatory growth, no significant differences were found among groups for heart, liver, pancreas, spleen, thymus, or bursa of Fabricius indices ($P>0.05$). (4) Post-restriction, the feed intake restriction group had significantly lower tibia weight, tibia length, tibia diameter, femur weight, and femur length compared to the other groups ($P<0.05$), while both the feed intake and energy restriction groups showed significantly lower femur diameter than the control and protein restriction groups ($P<0.05$). Following compensatory growth, no significant differences in any skeletal traits were observed among all groups ($P>0.05$). In conclusion, all three feed restriction methods reduced ADG and certain skeletal traits in AA broilers, with the feed intake restriction method having the most pronounced effects. After 21 days of compensatory growth, all restriction groups demonstrated compensatory growth effects, with skeletal traits showing no significant differences from the control group. However, since feed intake restriction decreased overall ADG and final body weight, this method should be applied cautiously in production practice.

Keywords: feed intake restriction; energy restriction; protein restriction; broiler chickens; compensatory growth; skeletal traits

Introduction

Modern commercial broiler chickens, when allowed ad libitum feeding, exhibit excessively rapid growth that often leads to metabolic disorders [1-2] and excessive fat accumulation [3], resulting in significant economic losses. These problems are largely attributable to genetic factors, nutrition, and their interactions, prompting increasing application of feed restriction techniques in broiler production [4]. Numerous studies have demonstrated that restricting nutrient intake during early growth stages can control growth and fat deposition [5], improve carcass quality [6-8], promote balanced development of organs and bones [9-10], enhance feed conversion efficiency and disease resistance [11-13], and reduce the incidence of sudden death syndrome [14-15], with weight losses during restriction being recoverable through subsequent compensatory growth [16-17].

In broiler management, feed restriction is typically implemented through either feed quality restriction or feed quantity restriction [18]. Quality restriction involves diluting or reducing specific nutrient concentrations without limiting feed amount, while quantity restriction limits feed intake or feeding time without altering nutrient density. Arbor Acres (AA) broilers are characterized by rapid growth, strong adaptability, high feed conversion efficiency, uniform development, well-developed breast and leg muscles, and excellent carcass quality. This study employed three restriction methods—feed intake restriction, energy restriction, and protein restriction—during early growth, followed by a compensatory growth period, to investigate their effects on growth performance, slaughter performance, and skeletal traits. The objective was to explore the practical value of feed restriction and compensatory growth technologies in broiler production and provide reference materials for their broader application.

Materials and Methods

1.1 Experimental Animals and Design

Five hundred fast-growing AA white-feathered broiler chicks (1 day old) were initially raised. At 7 days of age, 80 birds with similar body weight and health status were selected and randomly divided into four groups: control, feed intake restriction, energy restriction, and protein restriction, with 20 birds per group (equal sex ratio). Each bird was housed in an individual cage. From days 8 to 21, the control group received ad libitum feeding, while the energy and protein restriction groups had their metabolizable energy or crude protein intake reduced by 15%, respectively. The feed intake restriction group was allowed ad libitum access only from 08:00 to 13:00 daily, with feed removed thereafter to achieve quantitative restriction. From days 22 to 42, all restricted groups received ad libitum feeding to allow for 21 days of compensatory growth.

1.2 Experimental Diets

Diet formulations followed China' s "Feeding Standard of Chickens" (NY/T 33—2004). During the restriction phase, the control and feed intake restriction groups received diets formulated for white-feathered broiler starters. The energy restriction diet contained 85% of the metabolizable energy level of the control diet, with other nutrients identical. The protein restriction diet contained 85%

of the crude protein level of the control diet, with other nutrients unchanged. All diets were fed as mash. The control, energy restriction, and protein restriction groups received their respective diets ad libitum, with daily feed intake recorded. The feed intake restriction group received ad libitum access from 08:00 to 13:00 daily, after which feed was removed and daily intake recorded. During the compensatory growth phase, all groups received the same diet formulated for white-feathered broiler growers. Diet composition and nutrient levels are presented in .

1.3 Management

The experiment was conducted at the animal research facility of Henan Agricultural University. All birds were individually caged. Feed was provided at 08:00 daily, with water available ad libitum. Lighting was maintained at 23 hours per day. The facility was disinfected twice weekly, with regular cleaning to maintain hygiene. Temperature and humidity were controlled according to AA broiler requirements. Routine immunization protocols for AA broilers were followed, and daily records of feed intake and bird condition were maintained.

1.4 Measurements

1.4.1 Growth Performance Morbidity and mortality were recorded throughout the experiment. Body weight was measured at 21 days (after 14 days of restriction) and 42 days (after 21 days of compensatory growth) following an 8–12 hour fast. Based on initial weight, final weight, and feed intake, average daily gain (ADG), average daily feed intake (ADFI), and feed-to-gain ratio (F/G) were calculated for each phase.

1.4.2 Slaughter Performance At 22 days (post-restriction) and 43 days (post-compensatory growth), eight fasted birds per group were randomly selected, weighed, and slaughtered. Under sterile conditions, breast muscle, leg muscle, abdominal fat (including abdominal and gizzard fat), heart, liver, spleen, pancreas, thymus, and bursa of Fabricius were collected. Semi-eviscerated weight, eviscerated weight, breast muscle weight, leg muscle weight, and abdominal fat weight were recorded to calculate:

- Semi-eviscerated yield (%) = (semi-eviscerated weight/live weight) × 100
- Eviscerated yield (%) = (eviscerated weight/live weight) × 100
- Breast muscle percentage (%) = (breast muscle weight/live weight) × 100
- Leg muscle percentage (%) = (leg muscle weight/live weight) × 100
- Abdominal fat percentage (%) = (abdominal fat weight/live weight) × 100

1.4.3 Organ Indices Organs collected from the 22- and 43-day-old slaughtered birds were weighed to calculate:

- Heart index (%) = (heart weight/live weight) × 100

- Liver index (%) = (liver weight/live weight) × 100
- Pancreas index (%) = (pancreas weight/live weight) × 100
- Spleen index (%) = (spleen weight/live weight) × 100
- Thymus index (%) = (thymus weight/live weight) × 100
- Bursa of Fabricius index (%) = (bursa weight/live weight) × 100

1.4.4 Skeletal Traits Tibia and femur bones collected from the 22- and 43-day-old birds were weighed, and their length and diameter (at the narrowest point) were measured using vernier calipers.

1.5 Statistical Analysis

Data were analyzed using one-way ANOVA in SPSS 19.0. When significant differences among groups were detected, Duncan' s multiple range test was applied for pairwise comparisons between restriction groups and the control group.

Results

2.1 Effects on Growth Performance

As shown in , after 14 days of feed restriction, ADFI did not differ significantly among the control, energy restriction, and protein restriction groups (P>0.05), but all were significantly higher than the feed intake restriction group (P<0.05). ADG in all three restriction groups was significantly lower than in the control group (P<0.05), with the feed intake restriction group showing significantly lower ADG than both the energy and protein restriction groups (P<0.05). No significant difference in ADG was observed between the energy and protein restriction groups (P>0.05). The control group had a significantly lower F/G ratio than all restriction groups (P<0.05).

Following 21 days of compensatory growth, final body weight in the energy and protein restriction groups did not differ significantly from the control group (P>0.05), whereas the feed intake restriction group remained significantly lighter (P<0.05). No significant differences were observed among groups in ADFI, ADG, or F/G during the compensatory growth phase (P>0.05). Analysis of the entire restriction-compensation period revealed no significant differences in ADFI among the control, energy restriction, and protein restriction groups (P>0.05), though all were significantly higher than the feed intake restriction group (P<0.05). Both the feed intake and energy restriction groups had significantly lower ADG than the control group (P<0.05), while no significant differences in F/G were detected among all groups (P>0.05).

2.2 Effects on Slaughter Performance

As presented in , after 14 days of restriction, the energy and protein restriction groups showed no significant differences from the control group in eviscerated yield, semi-eviscerated yield, or breast muscle percentage (P>0.05), but all were significantly higher than the feed intake restriction group (P<0.05). Leg muscle percentage did not differ significantly among groups (P>0.05). Abdominal fat percentage in both the feed intake and energy restriction groups was significantly lower than in the protein restriction and control groups (P<0.05).

After 21 days of compensatory growth, the protein restriction group exhibited significantly higher eviscerated yield than the feed intake restriction group (P<0.05). Semi-eviscerated yield in the protein restriction and control groups was significantly higher than in the feed intake and energy restriction groups (P<0.05). No significant differences were observed among groups in breast or leg muscle percentages (P>0.05). However, the feed intake restriction group showed significantly higher abdominal fat percentage than the control group (P<0.05).

2.3 Effects on Organ Indices

As shown in , after 14 days of restriction, the energy restriction group had a significantly higher heart index than the protein restriction group (P<0.05). The protein restriction group exhibited a significantly higher liver index than the other three groups (P<0.05). The feed intake restriction group showed a significantly higher pancreas index than all other groups (P<0.05), while the control group had a significantly higher spleen index (P<0.05). The feed intake restriction group displayed a significantly lower thymus index than the control and protein restriction groups (P<0.05), and the energy restriction group had a significantly higher bursa of Fabricius index than the protein restriction group (P<0.05).

Following 21 days of compensatory growth, no significant differences were detected among groups for any organ indices, including heart, liver, pancreas, spleen, thymus, or bursa of Fabricius (P>0.05).

2.4 Effects on Skeletal Traits

As illustrated in , after 14 days of restriction, the feed intake restriction group had significantly lower tibia weight and length compared to all other groups (P<0.05). The energy restriction group also showed significantly lower tibia weight and length than the control group (P<0.05), and the protein restriction group had significantly lower tibia length than the control group (P<0.05). Tibia diameter, femur weight, and femur length in the feed intake restriction group were significantly lower than in the control, energy restriction, and protein restriction groups (P<0.05). Femur diameter in both the feed intake and energy restriction groups was significantly lower than in the control and protein restriction groups (P<0.05).

After 21 days of compensatory growth, no significant differences were observed among groups for any skeletal traits, including tibia weight, length, diameter, or femur weight, length, and diameter (P>0.05).

Discussion

3.1 Effects on Growth Performance

Feed restriction in broiler management primarily involves limiting either feed quality or quantity [18]. Quality restriction includes energy and protein restriction methods. Numerous studies demonstrate that restricting early nutrient intake controls growth and fat deposition while promoting balanced early development [19], reducing ascites syndrome, leg disorders, and sudden death syndrome [19], with weight losses being recoverable through compensatory growth [16]. In this study, AA broilers were subjected to feed intake, 15% energy, and 15% protein restriction from days 8–21, followed by compensatory growth from days 22–42.

During the restriction period, ADFI did not differ among the control, energy restriction, and protein restriction groups but was significantly higher than in the feed intake restriction group. All three restriction groups had significantly lower ADG than the control group, with the feed intake restriction group showing the lowest ADG. The control group had the lowest F/G ratio, while the feed intake restriction group had the highest F/G despite the lowest ADFI. During the compensatory growth phase (days 22–42), no significant differences were observed among groups in ADFI, ADG, or F/G, with the feed intake restriction group actually showing the lowest F/G. Over the entire experimental period, the feed intake and energy restriction groups had significantly lower ADG than the control group, while no significant differences in F/G were detected among all groups, though the feed intake restriction group maintained the lowest ADG and F/G.

These findings align with previous research. Wang et al. [20] reported that 30% energy restriction in 4–8 week-old Hubbard hens significantly reduced body weight and ADG compared to ad libitum feeding. Liu et al. [21] found that energy restriction significantly reduced growth performance during restriction in 2–6 week-old Sanhuang chickens, with complete compensatory growth observed after 35 days. Su et al. [22] noted that restricted AA broilers outperformed controls in growth rate during days 10–16. In our study, F/G was significantly higher in restricted groups during restriction but showed no differences after 21 days of compensatory growth, indicating adequate compensatory effects, consistent with previous findings. However, despite the lowest F/G ratio overall, the feed intake restriction group had 13.33% lower ADG and significantly lower market weight than the control group. Therefore, while simple feed intake restriction may improve feed efficiency, it reduces overall growth rate and final body weight, suggesting that this method should be applied cautiously in production.

3.2 Effects on Slaughter Performance

Breast and leg muscle percentages directly reflect meat production capacity in poultry. Our results showed that after restriction, the feed intake restriction group had lower breast muscle percentage than other groups, but after compensatory growth, no significant differences existed among groups in breast or leg muscle percentages. This indicates that while feed intake restriction temporarily impairs meat production performance, compensatory growth eliminates these differences.

Consistent with our findings, Niu et al. [23] reported that 50% feed intake restriction for 1–3 days in 8-day-old Avian broilers did not affect dressing percentage or carcass meat yield. Yang et al. [24] found that 10% or 20% feed restriction during days 10–20 did not affect eviscerated yield, breast muscle percentage, or leg muscle percentage in Avian broilers. Wu et al. [25] observed no significant effects of early feed restriction on carcass quality in AA broilers. Abdominal fat percentage is a key indicator of carcass quality; excessive abdominal fat reduces feed efficiency and increases processing costs. In our study, abdominal fat was lower in the feed intake and energy restriction groups after restriction but higher in all restriction groups after compensatory growth, suggesting that restricted birds consumed more feed to achieve compensatory growth, leading to increased fat deposition. Lippens et al. [26] similarly reported increased abdominal fat percentage with feed restriction. Thus, moderate restriction intensity and duration do not significantly affect breast or leg muscle percentages but may increase abdominal fat percentage, consistent with previous research.

3.3 Effects on Organ Indices

Normal visceral organ development is fundamental to physiological function, and organ indices reflect metabolic activity and functional capacity. In this study, significant differences in organ indices were observed among restriction groups and the control group after 14 days of restriction, but these differences disappeared after 21 days of compensatory growth, indicating that the three restriction methods do not impair long-term visceral organ development.

Immune organ development directly affects immune response strength and overall immunity. Higher spleen, thymus, and bursa of Fabricius indices indicate stronger immunity. In our study, spleen index was higher at 42 days than at 21 days, while thymus and bursa indices were lower at 42 days. This aligns with Yue et al. [19], who reported decreasing thymus and bursa indices and increasing spleen index with age, and with Li et al. [27], who found that feed restriction inhibited spleen index increase while suppressing thymus and bursa index decline.

3.4 Effects on Skeletal Traits

After 14 days of restriction, the feed intake restriction group showed inferior tibia and femur development compared to the other groups. Energy and protein restriction groups showed minimal differences in bone growth metrics and no significant differences in femur traits compared to the control group, suggesting that energy and protein restriction do not affect femur development. After 21 days of compensatory growth, no significant differences existed among groups for any tibia or femur traits, indicating that these restriction methods do not affect skeletal status at market age.

These findings differ from Bruno et al. [28] and Wang et al. [29], who reported significant effects of restriction on tibia growth. Bruno et al. [28] restricted broilers to 40% of ad libitum intake from days 7-14 and found reduced tibia and femur growth. Wang et al. [29] applied 10% energy restriction during days 8-14 and observed superior tibia growth in restricted groups. These discrepancies may be attributed to differences in restriction duration and breed. In our study, AA broilers showed no significant differences in tibia or femur traits among groups after 21 days of compensatory growth, demonstrating that these restriction methods do not impair skeletal development during the compensatory growth period.

Conclusion

Three key findings emerge from this study. First, all three feed restriction methods reduced ADG and certain skeletal traits in AA broilers, with feed intake restriction having the most pronounced effects on ADG and skeletal development, while protein restriction had the least impact. Second, after 21 days of compensatory growth, all restriction groups exhibited compensatory growth effects, with no significant differences in organ indices or skeletal traits compared to the control group. Third, although feed intake restriction improved feed efficiency, it reduced overall ADG and final body weight. Therefore, we recommend cautious application of feed intake restriction methods in commercial broiler production.

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Note: Figure translations are in progress. See original paper for figures.