# Effects of Different Feed Restriction Methods on Growth Performance, Slaughter Performance, and Skeletal Traits of Arbor Acres Broiler Chickens (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 skeletal 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 (at 21 days of age) and 21 days of compensatory growth (at 42 days of age), 8 chickens from each group were slaughtered to collect breast muscle, leg muscle, abdominal fat, heart, liver, spleen, thymus, bursa of Fabricius, bones and other tissues for weighing, as well as to measure bone length and diameter. The results showed: 1) After feed restriction, the average daily gain (ADG) of broilers in the three restriction groups was significantly lower than that of the control group ($P<0.05$). After compensatory growth, no significant differences were observed among groups in average daily feed intake (ADFI), ADG, and feed conversion ratio (FCR) of broilers ($P>0.05$), 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 of the control group ($P<0.05$), and the abdominal fat percentage of broilers in both the feed quantity restriction group and energy restriction group was significantly lower than that of the protein restriction group and control group ($P<0.05$). After compensatory growth, no significant differences were found 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 of 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 of the other three groups ($P<0.05$), the pancreas index of broilers in the feed quantity restriction group was significantly higher than that of 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, no significant differences were observed among groups in heart index, liver index, pancreas index, spleen index, thymus index, or bursa of Fabricius index of broilers ($P>0.05$). 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 of the other three groups ($P<0.05$), and the femur diameter of broilers in both the feed quantity restriction group and energy restriction group was significantly lower than that of the control group and protein restriction group ($P<0.05$). After compensatory growth, no significant differences were found in tibia weight, tibia length, tibia diameter, femur weight, femur length, or femur diameter among all groups ($P>0.05$). It can be concluded that all three feed restriction methods reduced the ADG and some skeletal trait indicators of AA broilers, with the feed quantity restriction group having the greatest impact on ADG and skeletal traits. After 21 days of compensatory growth, all three restriction groups exhibited compensatory growth effects, with no significant differences in skeletal traits between the restriction groups and the control group; however, the feed quantity restriction method reduced the overall ADG and final body weight of broilers, suggesting that this method should be used with caution in production.

## Full Text

## Abstract

This experiment was conducted to investigate the effects of different feed restriction methods on the growth performance, slaughter performance, and skeletal traits of Arbor Acres (AA) broiler chickens. Eighty 7-day-old AA broilers with similar body weight and health status were randomly allocated to four groups: a control group, a feed intake restriction group, an energy restriction group, and a protein restriction group, with 20 birds 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 birds 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, and 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 ($P<0.05$). After compensatory growth, there were no significant differences in average daily feed intake (ADFI), ADG, or feed-to-gain ratio (F/G) among groups ($P>0.05$), although the final body weight of the feed intake restriction group remained significantly lower than the control group ($P<0.05$). 2)

Following restriction, the eviscerated yield, semi-eviscerated yield, breast muscle percentage, leg muscle percentage, and abdominal fat percentage of the feed intake restriction group were significantly lower than those of the control group ($P<0.05$), while the abdominal fat percentages of both the feed intake restriction and energy restriction groups were significantly lower than those of the protein restriction and control groups ($P<0.05$). After compensatory growth, no significant differences were observed in breast muscle or leg muscle percentages among groups ($P>0.05$), but the abdominal fat percentage of the feed intake restriction group was significantly higher than that of the control group ($P<0.05$). 3) Post-restriction, the liver index of the protein restriction group and the pancreas index of the feed intake restriction group were significantly higher than those of the other three groups ($P<0.05$), whereas the spleen index of the control group was significantly higher than that of all restriction groups ($P<0.05$). After compensatory growth, no significant differences were found in heart, liver, pancreas, spleen, thymus, or bursa of Fabricius indices among groups ($P>0.05$). 4) After restriction, the tibia weight, tibia length, tibia diameter, femur weight, and femur length of the feed intake restriction group were significantly lower than those of the other three groups ($P<0.05$), while the femur diameter of both the feed intake restriction and energy restriction groups was significantly lower than that of the control and protein restriction groups ($P<0.05$). Following compensatory growth, no significant differences were detected in any skeletal traits among 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 greatest impact on ADG and skeletal development. After 21 days of compensatory growth, all restriction groups exhibited compensatory growth effects, and their skeletal traits did not differ significantly from the control group. However, feed intake restriction reduced overall ADG and final body weight, suggesting that this method should be applied cautiously in production.

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

## Introduction

Modern commercial broiler chickens tend to grow excessively fast when fed ad libitum, which can lead to metabolic disorders [?, ?] and excessive fat deposition [?], resulting in significant economic losses. These problems arise largely from genetic and nutritional factors and their interactions, prompting increasing application of feed restriction techniques in broiler production [?]. Numerous studies have demonstrated that restricting nutrient intake during early growth can control development and fat deposition [?], improve carcass quality [?], promote balanced development of organs and bones [?], enhance feed conversion efficiency and disease resistance [?], and reduce the incidence of sudden death syndrome [?]. Weight loss during restriction can be compensated through subsequent compensatory growth [?, ?].

Common feed restriction methods in broiler management include qualitative restriction and quantitative restriction [?]. Qualitative restriction involves diluting or reducing specific nutrient concentrations without limiting feed amount, while quantitative restriction limits feed quantity or access time without altering nutrient density. Arbor Acres (AA) broilers are characterized by rapid growth, strong adaptability, high feed conversion efficiency, uniform development, and excellent breast and leg muscle yield with good carcass quality. This study employed feed intake restriction, energy restriction, and protein restriction during early growth, followed by a compensatory growth period, to evaluate the effects of these three restriction methods and subsequent compensatory growth on growth performance, slaughter performance, and skeletal traits of AA broilers. The aim was to explore the practical value of feed restriction and compensatory growth techniques in broiler production and provide reference materials for wider application of these methods.

## Materials and Methods

### Experimental Animals and Design

Five hundred fast-growing AA white-feathered broilers (1-day-old) were raised to 7 days of age. Eighty birds with similar body weight and health status were then selected and randomly divided into four groups: control, feed intake restriction, energy restriction, and protein restriction, with 20 birds per group (half male and half female). Each bird was housed in an individual cage. From 8 to 21 days of age, the control group received ad libitum feeding. The energy and protein restriction groups had their metabolizable energy or crude protein intake limited to 85% of the control group, respectively, while the feed intake restriction group was allowed to feed ad libitum from 08:00 to 13:00 daily, after which feed was removed to achieve total quantity restriction. From 22 to 42 days of age, all restricted groups were returned to ad libitum feeding for a 21-day compensatory growth period.

### Experimental Diets

Diet formulations followed the Chinese Feeding Standard for 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 was formulated to provide 85% of the metabolizable energy of the control diet, with other nutrient levels identical to the control. The protein restriction diet contained 85% of the crude protein of the control diet, with other nutrients unchanged. All diets were provided as mash. The control, energy restriction, and protein restriction groups had continuous access to feed, with daily intake recorded. The feed intake restriction group had ad libitum access from 08:00 to 13:00, 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 .

### Animal Management

The experiment was conducted at the animal research facility of Henan Agricultural University. All birds were housed in individual cages. Feed was provided daily at 08:00, with water available ad libitum. Lighting was maintained for 23 hours daily. The house was disinfected twice weekly, and sanitation was maintained regularly. 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.

### Measurement Indices

**Growth Performance** Mortality was recorded throughout the experiment. Body weight was measured after an 8–12 hour fast at 21 days (post-restriction) and 42 days (post-compensatory growth). 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.

**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, eviscerated yield, breast muscle percentage, leg muscle percentage, and abdominal fat percentage using the following formulas:

- 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

**Organ Indices** For the birds slaughtered at 22 and 43 days, the heart, liver, pancreas, spleen, thymus, and bursa of Fabricius were weighed to calculate organ indices:

- 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

**Skeletal Traits** From the same slaughtered birds, tibia and femur bones were collected and weighed. Length and diameter (at the narrowest point) were measured using vernier calipers.

### Statistical Analysis

Experimental data were analyzed using one-way ANOVA in SPSS 19.0. When significant differences were detected among groups, Duncan' s multiple range test was used for pairwise comparisons. Significance was declared at P<0.05.

## Results

### Effects of Different Feed Restriction Methods 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). The ADG of all three restriction groups was significantly lower than that of the control group (P<0.05), with the feed intake restriction group being significantly lower 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 F/G of the control group was significantly lower than that of all restriction groups (P<0.05).

After 21 days of compensatory growth, the final body weight of 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 lower (P<0.05). No significant differences were observed in ADFI, ADG, or F/G among any groups during the compensatory growth phase (P>0.05). Analysis of the entire restriction-compensatory growth 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). The ADG of the feed intake restriction and energy restriction groups was significantly lower than that of the control group (P<0.05), while no significant differences in F/G were detected among all groups (P>0.05).

### Effects of Different Feed Restriction Methods on Slaughter Performance

presents the slaughter performance data. After 14 days of restriction, the eviscerated yield, semi-eviscerated yield, and breast muscle percentage of the energy and protein restriction groups did not differ significantly from the control group (P>0.05) but were significantly higher than those of the feed intake restriction group (P<0.05). No significant differences in leg muscle percentage were observed among groups (P>0.05). The abdominal fat percentages of the feed intake restriction and energy restriction groups were significantly lower than those of the protein restriction and control groups (P<0.05).

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

### Effects of Different Feed Restriction Methods on Organ Indices

As presented in , after 14 days of feed restriction, the heart index of the energy restriction group was significantly higher than that of the protein restriction group (P<0.05). The liver index of the protein restriction group was significantly higher than that of the other three groups (P<0.05). The pancreas index of the feed intake restriction group was significantly higher than that of all other groups (P<0.05). The spleen index of the control group was significantly higher than that of the three restriction groups (P<0.05). The thymus index of the feed intake restriction group was significantly lower than that of the control and protein restriction groups (P<0.05). The bursa of Fabricius index of the energy restriction group was significantly higher than that of the protein restriction group (P<0.05).

After 21 days of compensatory growth, no significant differences were observed in heart, liver, pancreas, spleen, thymus, or bursa of Fabricius indices among any groups (P>0.05).

### Effects of Different Feed Restriction Methods on Skeletal Traits

shows the skeletal trait measurements. After 14 days of restriction, tibia weight and length in the feed intake restriction group were significantly lower than those in the other three groups (P<0.05). The energy restriction group also had significantly lower tibia weight and length compared to 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 those in the control, energy restriction, and protein restriction groups (P<0.05). The femur diameter of both the feed intake restriction and energy restriction groups was significantly lower than that of the control and protein restriction groups (P<0.05).

Following 21 days of compensatory growth, no significant differences were detected in tibia weight, tibia length, tibia diameter, femur weight, femur length, or femur diameter among any groups (P>0.05).

## Discussion

### Effects on Growth Performance

Common feed restriction methods in broiler production involve limiting either feed quality or quantity [?]. Qualitative restriction includes energy and protein limitation. Numerous studies have shown that restricting early nutrient intake can control growth and fat deposition [?], reduce the incidence of ascites syndrome, leg disorders, and sudden death syndrome [?], with weight loss during restriction being recoverable through compensatory growth [?]. In this study, AA broilers were subjected to feed intake restriction, 15% energy restriction, or 15% protein restriction from 8 to 21 days of age, followed by compensatory growth from 22 to 42 days.

During the restriction period, ADFI did not differ significantly among the control, energy restriction, and protein restriction groups but was significantly higher than in the feed intake restriction group. The ADG of all three restriction groups was significantly lower than that of the control group, with the feed intake restriction group showing the lowest ADG. The control group had the lowest F/G, while the feed intake restriction group had the highest F/G despite the lowest ADFI. After 21 days of compensatory growth, no significant differences in ADFI, ADG, or F/G were observed among groups, with the feed intake restriction group showing the lowest F/G during this phase. Over the entire experimental period, the ADG of the feed intake restriction and energy restriction groups remained significantly lower than the control group, though no significant differences in F/G were detected among groups, with the feed intake restriction group maintaining the lowest ADG and F/G.

These findings align with previous research. Wang et al. [?] reported that 30% energy restriction in 4–8 week-old Hubbard hens significantly reduced body weight and ADG at 8 weeks. Liu et al. [?] observed that energy restriction significantly reduced growth performance during restriction in Sanhuang chickens, with complete compensatory growth observed after 35 days. Su et al. [?] found that restricted broilers outperformed controls in growth rate during 10–16 days of age. In the current study, F/G was significantly higher in restriction groups during the restriction phase but did not differ significantly after compensatory growth, indicating that appropriate restriction can elicit sufficient compensatory growth effects, consistent with previous findings. However, despite having the lowest F/G overall, the feed intake restriction group exhibited 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 ADG and market weight, warranting cautious application in production.

### Effects on Slaughter Performance

Breast and leg muscle percentages directly reflect meat production capacity. In this study, the feed intake restriction group had lower breast muscle percentage after restriction, but after compensatory growth, no significant differences in breast or leg muscle percentages were observed among groups. This indicates that while feed intake restriction temporarily reduced meat production capacity, compensatory growth eliminated these differences. Niu et al. [?] 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. [?] found that 10% or 20% feed restriction from 10–20 days of age did not affect eviscerated yield, breast muscle percentage, or leg muscle percentage. Wu et al. [?] observed that 20% restriction for 7 days starting at 6, 9, or 12 days of age had no significant effect on carcass quality. Abdominal fat percentage is a key indicator of carcass quality; excessive abdominal fat reduces feed efficiency and increases processing costs. In this study, abdominal fat percentages were lower in the feed intake restriction and energy restriction groups after restriction but higher in all restriction groups after compensatory growth, suggesting that restricted birds consumed more feed during re-alimentation, leading to increased fat deposition. Lippens et al. [?] similarly reported that feed restriction increased abdominal fat percentage. These results confirm that moderate restriction does not significantly affect breast or leg muscle percentages but can increase abdominal fat percentage after compensatory growth.

### Effects on Organ Indices

Normal development of visceral organs is essential for 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 after 14 days of restriction, but these differences disappeared after 21 days of compensatory growth, indicating that the three restriction methods did not impair visceral organ development. Immune organ development directly affects immune response strength and overall immunity. Higher spleen, thymus, and bursa indices indicate stronger immunity. In this study, spleen index at 42 days was higher than at 21 days, while thymus and bursa indices were lower at 42 days. This pattern aligns with Yue et al. [?], who reported that thymus and bursa indices decrease while spleen index increases with age, and with Li et al. [?], who found that feed restriction inhibits spleen index increase and attenuates the decline in thymus and bursa indices.

### Effects on Skeletal Traits

After 14 days of restriction, the feed intake restriction group exhibited inferior tibia and femur development compared to the other groups. The energy and protein restriction groups showed similar bone growth to each other, with no significant differences in femur traits compared to the control group, suggesting that energy and protein restriction did not affect femur development. After 21 days of compensatory growth, no significant differences were observed in any skeletal traits among groups, indicating that these restriction methods did not affect bone development at market age. These findings differ from Bruno et al. [?] and Wang et al. [?], who reported that restriction affected tibia growth.

Bruno et al. [?] restricted broilers to 40% of ad libitum intake from 7-14 days and found reduced tibia and femur growth. Wang et al. [?] reported that 10% energy restriction in 8-14 day-old broilers resulted in better tibia growth than controls. These discrepancies may be attributed to differences in restriction duration and breed. In the current study, after 21 days of compensatory growth, no significant differences in tibia or femur traits were observed among groups at 42 days of age, demonstrating that these restriction methods did not affect bone development during the compensatory growth period.

## Conclusion

All three feed restriction methods reduced ADG and certain skeletal traits in AA broilers, with feed intake restriction having the greatest impact on ADG and skeletal development, and protein restriction having the least impact. 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. However, feed intake restriction reduced overall ADG and final body weight, suggesting that this method should be applied cautiously in commercial production.

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