



Impact of every-day versus skip-a-day feeding of broiler breeder pullets during rearing on body weight uniformity and reproductive performance

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ABSTRACT Genetic selection for increased growth rate in broilers makes feed restriction programs such as skip-a-day (**SAD**) feeding, for broiler breeders essential to managing body weight, flock uniformity, and reproductive performance. The objective of this experiment was to compare intestinal development, weight gain of breeder pullets, and reproductive performance (22–45 wk) when fed a high fiber diet (3.8% crude fiber) on either an every-day (ED) or SAD basis during rearing. The same developer ration and feed amounts were fed to both treatments. Day-old Ross 708 pullet chicks (n = 912) were randomly distributed into 4 floor pens (n = 228/pen, 2 pens/treatment). At 20 wk of age all birds were weighed, and the coefficient of variation (CV) and average body weight was calculated for each treatment. Birds were then distributed into 10 lay pens (n = 35 birds/pen, 5 pens/treatment) at 21.5 wk of age. Light was increased from 8 h to 15.25 h at move to the

lay facility, and all birds were daily fed for the remainder of the study. Data were analyzed by SAS SLICE using a significance level of $P \leq 0.05$. During lay, 25% of the birds from each treatment were weighed weekly to adjust feed and monitor body weight. At 21 wk the ED fed pullets were more uniform ($P = 0.0007$) than the SAD fed pullets. Eggs were collected daily and set for hatch every 4 wk from 28 to 42 wk of age. No significant difference in the hatch data were observed. The ED fed birds achieved first egg at 166 d of age while the SAD fed birds achieved first egg at 173 d of age. Specific gravity was measured every 2 wk from 30 to 40 wk, with ED reared birds having better overall eggshell quality ($P = 0.02$) and greater egg weight ($P < 0.0001$) than those fed SAD. Feeding a high fiber diet on an ED basis during rearing, improved body weight uniformity in rearing, encouraged early lay, improved eggshell quality and increased egg weight.

Key words: ED feeding, shell quality, body weight uniformity, broiler breeder pullet, intestinal development

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INTRODUCTION

Broiler growth rate has increased through genetic selection leading to a critical need for feed restriction programs for broiler breeders to control body weight (**BW**) and reproductive efficiency (Harms and Ivey, 1992; Robinson et al., 1993; Lopez and Lesson, 1995; de Beer and Coon, 2006). The skip-a-day (**SAD**) feeding program became the method of choice for feed restricting broiler breeders due to its ease of application, good results, and ample feed distribution (Hudson et al., 1999). When using a SAD feeding method, feed cleanup time is increased,

which allows for more equal opportunities for feed intake thus a more uniform flock. The body weight uniformity of the flock is critical for broiler breeder management because it impacts feed allocation, egg size uniformity, and incubation conditions.

Feed restriction is critical for managing broiler breeders to mitigate excessive BW gain as well as over fleshing. Without the feed restriction programs, broiler breeders will develop severe health and reproductive dysfunction (ruptured tendons, lameness, decreased livability, poor fertility, decreased laying performance) once in the lay period (Hocking and Duff, 1989; de Beer and Coon, 2006; de Jong and Guémené, 2011). While feed restriction assists to manage BW and production goals it cannot be ignored that there are negative impacts of feed restricting broiler breeders. Female broiler breeders are feed restricted to approximately 25 to 55% of their ad libitum feed intake during rearing

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(Savory et al., 1996) which can lead to chronic hunger and feeding anxiety as well as general welfare issues (Aranibar et al., 2020). Every-day (ED) feeding pullets would help to alleviate some welfare issues. However, due to the use of high-density feeds commonly fed in the US poultry industry and the current widespread use of older chain and pan feeders, ED feeding is impractical and can lead to feed distribution issues, BW, and flock uniformity issues (Bartov et al., 1988). In contrast, SAD feeding physiologically disrupts the bird's natural tendency to forage daily. Richards et al. (2010) found birds on a SAD program were less feed-efficient due to their inability to store and mobilize nutrients when receiving such a large quantity one day and fasting the next.

One method to increase the success of an ED feeding program is to implement a low-density and high fiber diet. Feeding is a huge production cost and has evolved as such for rearing birds even though our understanding of physiology and metabolism of feedstuffs has advanced tremendously (Kiarie and Mills, 2019). Birds have a high sense of hunger which can be alleviated by low-density high-volume feeds. While the highly concentrated diets are easier to mill, store and transport they offer little assistance to improve feed distribution and a sense of satiety in the bird. Bulky high fiber diets however can assist in feed distribution issues as well as aiding in a sense of satiety in the bird (Savory et al., 1996). Understanding how these birds utilized these high fiber feed stuffs can assist in these production costs as well as potentially improve the bird's production goals. It is widely known that increasing dietary fiber in poultry diets impact the small intestine by increasing epithelial cell turnover rate, villi height, and intestinal viscosity (Chiou et al., 1996; Sklan et al., 2003; Tejada and Kim, 2020). The diet used for this experiment contained high fiber cereal grain feedstuffs (wheat middlings and whole oats) that are known to decrease the digestion of protein and fats due to the nonstarch polysaccharides (NSPs) surrounding the starch particles in the grain (Kumar et al., 2012). These products allow an increase in overall feed volume on each feed day while maintaining proper nutrition. To assist in increasing the volume and diluting the diet, whole oats were also utilized. Due to the hull of the oat, they are a fibrous feedstuff with approximately 75% as much energy as corn and are approximately 12% fiber (Commercial Production. Chicken, Meat and Egg, p 218). Research has shown that feeding fibrous products such as oats stimulates digestive tract development in pullets (Ernst et al., 1994).

The current study investigated if feeding broiler breeder pullets, a low-density high fiber diet on an ED feeding program can improve broiler breeder pullet intestinal development without causing a negative influence on overall performance. The main goal of this study was to determine if feeding ED or SAD impacted BW uniformity, performance, or intestinal development. So, both feeding methods received equal amounts of the same diet. The only difference being the delivery of feed either ED or SAD. Feeding large particle sizes of corn and whole oats as well as fibrous feedstuffs has the

potential to eliminate feed distribution issues on an ED feeding program as well as eliminate the need for a fasting day. We hypothesize that feeding broiler breeder pullets a low-density high fiber diet with large particle sizes on an ED basis will stimulate intestinal development in rearing and not negatively impact a flock's reproductive performance during the lay period.

MATERIALS AND METHODS

A total of 912 one-day-old (Ross 708) pullets were raised in 4 floor pens with new pine shavings in an environmentally controlled solid side wall poultry house. At 4 wk of age, 2 replicate pens ($7.3 \times 4.6 \text{ m}^2$, 228 pullets, $147.3 \text{ cm}^2/\text{bird}$) were allocated to each feeding program (456 birds/treatment). The 2 pens were housed in the same room separated by a chain-link partition and fed on the same feeding program. All birds were fed a standard starter ration (2,910 kcal/kg, 18% CP) for the first 3 wk of age, followed by a grower diet (2,820 kcal/kg, 15.4% CP, 1.07% Ca) to 22 wk of age (Table 1). A prebreeder diet (2,820 kcal/kg, 14.7% CP, 1.5% Ca) was used from 22 to 25 wk (Table 1) until the

Table 1. Composition of diets.

Ingredients, %	Grower	Prebreeder	Layer
Corn, coarse ground	57.21	59.20	60.39
Wheat middling's	16.03	16.39	7.00
Soybean meal	14.15	14.02	17.00
Oats, whole	8.00	4.00	4.00
Defluorinated Phosphorus	1.68	1.67	-
Dicalcium Phosphate	-	-	1.70
Limestone (fine)	1.20	2.49	3.80
Oyster shell (coarse)	-	0.50	3.80
Soybean oil	0.50	0.50	1.30
Salt	0.30	0.30	0.30
Choline chloride 60%	-	-	0.10
Trace mineral premix ^{1,2}	0.08 ¹	0.08 ¹	0.10 ²
Vitamin Premix ^{3,4}	0.80 ³	0.80 ³	0.03 ⁴
D3 premixed hand-add ⁵	-	-	0.25 ⁵
DL-methionine	0.05	0.05	0.19
L-threonine	-	-	0.04
Total	100.0	100.0	100.0
Calculated Analysis			
Crude Protein, %	15.4	14.7	14.8
Ca, %	1.07	1.50	3.40
P, %	0.72	0.80	0.60
Available P, %	0.44	0.40	0.30
Metabolizable energy, kcal per kg of diet	2,820.0	2,820.0	2,735.0
Digestible lysine, %	0.72	0.70	0.60
Digestible methionine, %	0.29	0.43	0.40

¹Supplied per kg of diet: Mn, 107.20 mg as Mn sulfate; Fe, 21.25 mg as ferrous sulfate; Cu, 3.20 mg as basic copper chloride; I, 0.80 mg as calcium iodate; Se, 0.32 mg as sodium selenite.

²Supplied per kg of diet: Mn, 109 mg as Mn sulfate; Zn, 90 mg as Zn sulfate; Fe, 27 mg as ferrous sulfate; Cu 7 mg as basic Cu chloride; I, 1.3 mg as ethylenediamine hydroiodide; Se, 0.3 mg as sodium selenite.

³Supplied per kg of diet: vitamin A, 17600 IU; vitamin D3, 3527 IU; vitamin E, 35.3 mg; vitamin B12, 0.04 mg; thiamine, 7.0 mg; riboflavin, 14.1 mg; menadione, 3.5 mg; vitamin B6, 7.0 mg; niacin, 141.0 mg; pantothenic acid, 35.2 mg; folic acid, 1.8 mg; biotin, 0.4 mg.

⁴Supplied per kg of diet: vitamin A, 11,000 IU; vitamin D3, 2,240 IU; vitamin E, 63 mg; vitamin K, 4.2 mg; thiamine, 3 mg; riboflavin, 12 mg; pyridoxin, 4.2 mg; cobalamin, 0.03 mg; niacin, 55 mg; pantothenic acid, 18.3 mg; folic acid, 2.8 mg; biotin, 0.46 mg.

⁵Supplied per kg of diet: 2,760 IU of D3 in addition to 2,240 IU already provided.

hens reached 5% egg production. For the lay portion of the study, they were fed a breeder diet (2,735kcal/kg, 14.8% CP, 3.4% Ca) from 25 to 45 wk (Table 1). The feeding programs (ED or SAD) were started at 4 wk and continued through 22 wk of age with 2 pens of pullets within a room receiving a limited amount of feed daily (everyday, ED) and the other 2 pens receiving twice their daily amount on 1-day and no feed on the following day (skip-a-day, SAD). Both groups received the same feed and same feed amount over a 2-d period as well as for the duration of the trial. During rearing, the pullets ate from a chain feeder (14.3 m, 6.3 cm/bird) and water was provided ad libitum by nipple drinker line (6.1 m with 40 nipples). All birds were wing banded at 4 wk of age to track growth rate. The photoperiod to 22 wk of age was 23 h of light:1 h of darkness (23L:1D) for the first 3 d, followed by an 8L:16D pattern until 22 wk of age. The photoperiod was increased to 15.25L:8.75D at 22 wk of age and remained constant until the end of the study at 45 wk of age.

At 21.5 wk pullets were distributed to 10 lay pens ($n = 35$ birds/pen, 5 pens/treatment) based on the 20 wk BW CV so that all pens within a treatment were similar to the rearing CV for that treatment. Lay pens were two-third raised slats and one-third litter, and each pen was equipped with a nest section of roll out nest containing 6 nest holes. Once moved to the lay facility all birds began feeding on a daily basis per industry standard. Through the production period, feed was adjusted based on weekly body weights and egg production according to the Aviagen Breeder Management Guide Recommendations (Aviagen, 2016). All birds were fed equal amounts of feed for the life of the flock.

Eggs were collected 4 to 5 times per day by pen and percentage total egg production calculated by week on a hen day basis (number of eggs laid per wk was divided by 7-d and by the number of birds per pen). Every 4 wk through 45 wk of age, eggs were collected and stored for no more than 7 d. From each treatment pen, 90 eggs were sorted and placed in a Natureform incubator (Jacksonville, FL) at 37.5°C and 53% relative humidity. Eggs were candled at 10 d of incubation to determine (%) fertility, early dead and cracked eggs. At hatch, all first quality chicks were counted to determine percentage hatchability. Unhatched eggs were opened, and middle and late dead embryos counted along with pipped, contaminated, abnormal shelled eggs and cull chicks and percentage of incubated eggs were calculated. All procedures were approved by the University of Georgia Animal Care and Use Committee.

TME_n Determination (in Leghorn roosters)

The nutrient availability in whole oats were determined by standard TME_n (Nitrogen-corrected true metabolizable energy) methods described by Sibbald (1976) and modified by Dale and Fuller (1984). Eight Single Comb White Leghorn roosters were fasted for 30 h to empty the digestive tract. Roosters were in an individual cage measuring 30 cm wide, 45 cm deep

and 50 cm high. Each cage was equipped with a nipple drinker for ad libitum access of water and a stainless-steel excreta collection pan. Roosters were precision fed 35 g of whole oats and excreta were collected for 48 h post feeding.

Excreta were collected from each individual pan, dried, and weighed. Crude protein and moisture of the feces and whole oats were determined (AOAC, 2006a,b, by the University of Georgia Agricultural and Environmental Laboratories, Athens, GA), with gross energy of feed and feces determined with a bomb calorimeter (University of Georgia Agricultural and Environmental Laboratories, Athens, GA).

Digestible Amino Acid Determination

The determination of the digestible amino acid coefficients of the whole oats followed the same procedures utilized for the TME_n determination except that cecectomized Single Comb White Leghorn roosters were utilized. The amino acid content of the whole oats and feces were determined (AOAC, 2006c, and University of Missouri Agricultural Experiment Station Chemical Laboratories, Columbia, MD) for calculation of the digestible amino acid coefficients for the whole oats.

Growth and Productivity

A sample of individual BW (25% of the birds from each pen) were taken prior to feeding (ad libitum water) during rearing weekly and all birds were weighed at 4, 8, 12, 16, and 20 wk. Once in lay, 25% of the birds from each treatment were weighed individually and approximately 7 h after feeding (ad libitum water) weekly through 45 wk of age. Coefficient of variation (CV) for BW was calculated on a per pen basis during rearing as a measure of flock uniformity. In lay, BW for each treatment was calculated per pen ($n = 35$ birds/pen, 350 birds/treatment and total of 700 birds). Egg production was determined on a daily per pen basis from 23 to 45 wk of age.

Digestive Tract Sample Collection

To evaluate the impact of ED feeding on digestive tract development and intestinal morphology 5 pullets from each pen were randomly selected at 8, 12, 16, and 20 wk of age for necropsy and morphometric analyses as described by (Teng et al., 2017). The entire digestive tract was removed, and individual parts were weighed, and their percentage of body weight was calculated. Samples of the duodenum, jejunum and ileum were taken and fixed with 10% buffered formalin. The duodenum sample was taken at the distal end and sliced approximately into 2 cm sections that included part of the pancreas. A section of the jejunum was taken by measuring using the Meckel's Diverticulum and placing it even with the distal end of the duodenum and cutting at the apex of the loop created. The ileum section taken

was created by taking Meckel's Diverticulum and placing it even with the proximal end of the ceca and slicing a 2 cm at the apex of the loop created. Routine tissue processing, embedding, sectioning, and staining of slides was performed for measuring villi height and crypt depth using Lecia Application Suite V 4.8 software program. The ratio of villi height and crypt depth was calculated.

Specific Gravity and Egg Weight

Specific gravity was measured using a flotation method as described by Harms et al. (1990). A days' worth of settable eggs from each pen ($n = 5$ pens/treatment) were collected every two weeks from 30 to 40 wk of age. Eggs were allowed to equilibrate to the temperature of the room that the saline solutions were stored in (21°C) for a minimum of twelve hours. Saline densities were as follows: 1.060, 1.065, 1.070, 1.075, 1.080, 1.085, 1.090, and 1.095 g per cm^3 . A weighted mean of eggshell quality was determined by pen.

A days' worth of settable eggs from each pen ($n = 5$ pens/treatment) were collected every 2 wk from 29 wk to 41 wk of age. Individual eggs were weighed using a Mettler Toledo bench scale (Mettler Toledo, Columbus, OH). An average egg weight was calculated per pen.

Statistical Analysis

Body weight, gastrointestinal measurements, egg production, hatch data, and specific gravity were analyzed using SLICE analysis (SAS Institute, 2013). Slice analysis specifies effects to test for differences between interactions LS-mean, to produce tests of simple effects (Winer, 1971). This method evaluates the effect of the treatment and minimizing the impact of time (week). Differences were deemed to be significant when the P -value was less than or equal to 0.05.

RESULTS

Body Weight and Uniformity

Body weight and body weight uniformity were not significantly different at 4 wk (ED 326.9 g, 20.5 CV and SAD 354.8 g, 22.5 CV) when the feeding treatment was implemented (Table 2). However, by 20 wk of age BW was significantly different ($P \leq 0.05$) between the feeding programs with the ED pullets being heavier than the SAD pullets (1948.1 g, 1895.6 g, respectively). Body weight was only significantly different at wk 23 and 34 during the laying period ($P < 0.05$) (data not shown). The ED feeding program significantly improved body weight uniformity at 12, 16, and 20 wk of age (Table 3). During the laying period, body weight uniformity did not differ between the hen groups fed either ED or SAD as pullets (data not shown).

Table 2. The mean body weight of pullets (g) at 4, 8, 12, 16, and 20 wk of age as affected by the skip-a-day and every-day feeding program (SAD and ED).

Weeks	SAD ^c	ED ^d
4	354.8 ^a	326.9 ^a
8	689.7 ^a	645.6 ^a
12	1057.8 ^a	1019.6 ^a
16	1474.6 ^a	1461.0 ^a
20	1895.6 ^b	1948.1 ^a

^{a-b}Treatments significant within period ($P < 0.05$).

^cSAD = Skip-a-day feeding program.

^dED = Every-day feeding program.

Table 3. The coefficient of variation of body weight (%) at 4, 8, 12, 16, and 20 wk of age during the rearing period as affected by the different feeding programs skip-a-day and every-day feeding program (SAD and ED).

Weeks	SAD ^c	ED ^d
4	22.5 ^a	20.5 ^a
8	18.8 ^a	16.1 ^a
12	17.9 ^b	13.1 ^a
16	16.8 ^b	11.9 ^a
20	15.8 ^b	11.2 ^a

^{a-b}Treatments significant within period ($P < 0.05$).

^cSAD = Skip-a-day feeding program.

^dED = Every-day feeding program.

Feed Intake and TMEn

Feed intake was the same throughout the study for both treatments and was adjusted weekly to meet recommended breeder target BW during rearing (data not shown). For the lay phase of the experiment (22–45 wk) feed intake also did not differ (data not shown).

The TMEn value of whole oats was approximately 9.8% CP (Table 4) and 11.5% fiber. Based on these findings we included whole oats at a rate of 8% in the grower diet (Table 1).

Table 4. Crude protein, amino acid content, and digestibility coefficient of whole oats.¹

Amino acid	Feed content (%)	Digestibility coefficient (%)
Crude Protein	9.82	
Alanine	0.450	79.7
Arginine	0.580	91.2
Aspartic Acid	0.760	84.0
Cysteine	0.310	80.1
Glycine	0.480	4.4
Glutamic Acid	1.820	91.5
Histidine	0.210	89.5
Isoleucine	0.370	83.1
Leucine	0.690	87.5
Methionine	0.160	81.4
Phenylalanine	0.480	88.3
Proline	0.490	87.6
Serine	0.400	83.6
Threonine	0.320	81.8
Tryptophan	0.090	89.5
Tyrosine	0.240	87.4
Valine	0.510	81.5

¹Values are reported on an as fed basis. The dry matter content of whole oats was 88%.

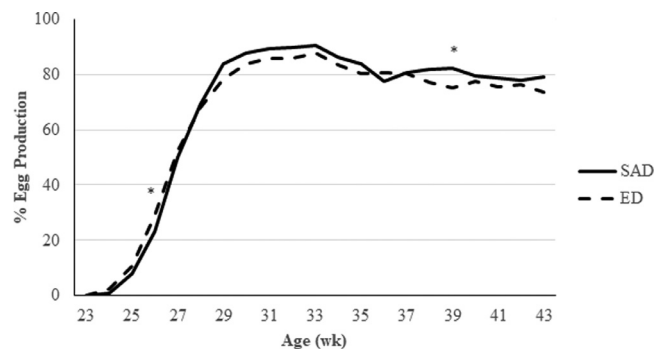


Figure 1. Egg production curve as affected by the different feeding programs. Feeding programs were as follows: SAD = skip-a-day feeding program (—), ED = every-day feeding program (- -). Each value represents the mean percentage of total eggs produced within each feeding program. There were significant differences ($P < 0.05$) between the feeding programs at 26 and 39 wk of age and no overall differences for the production period.

Egg production and Eggshell Quality

Hens fed on the ED program achieved first egg one week prior (166 d) to the hens fed on the traditional SAD feeding program (173 d) during rearing. Overall egg production was not significantly different between treatments. However, there were 2 wk that had significant differences in egg production at wk 26 ($P = 0.04$) and 39 ($P = 0.01$) (Figure 1). At wk 26, the hens that were fed ED during rearing had 6% better egg production than those fed SAD during rearing. At wk 39, those hens fed SAD during rearing had 7% better egg production than those fed ED during rearing. The weekly egg weights were not significantly different, but overall egg weights were significantly different from 29 to 41 wk of age (60.4 g and 59.1 g for the ED and SAD, respectively) (Figure 2).

Overall specific gravity was significantly different with hens fed on an ED basis having improved shell quality when compared to those fed SAD as pullets (Figure 3, $P = 0.02$). When compared by week the specific gravity comparisons were not different.

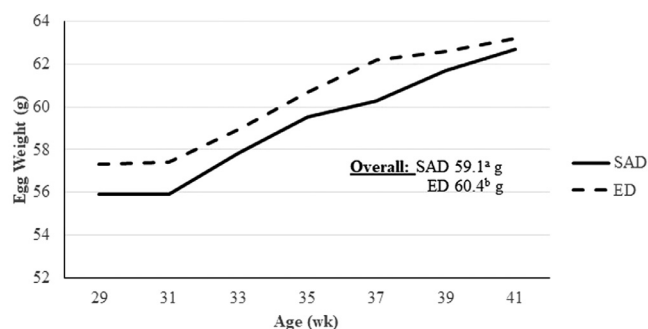


Figure 2. Mean egg weight affected by different feeding programs. Feeding programs are as follows: SAD = skip-a-day feeding program (—), ED = every-day feeding program (- -). Each value represents the mean weight of total eggs produced on a single day within each feeding program. The means for the overall period are 60.4 g and 59.1 g for the ED and SAD feeding programs, respectively. There were significant differences ($P < 0.001$) for the overall production period between the feeding programs.

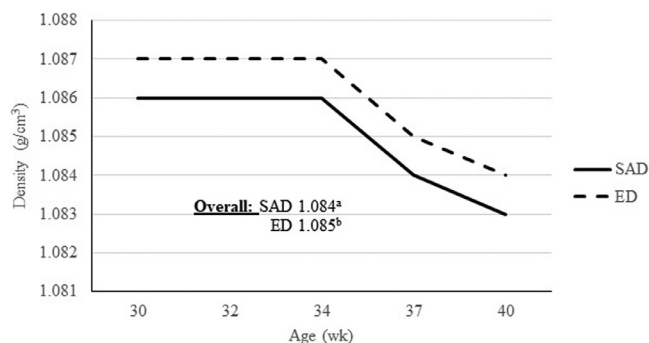


Figure 3. Mean eggshell density affected by different feeding programs during rearing. Feeding programs are as follows: SAD = skip-a-day feeding program (—), ED = every-day feeding program (- -). Each value represents a weighted average of eggshell density of the total number of eggs within each feeding program. Overall specific gravity was different between treatments ($P = 0.02$).

Intestinal Morphology and Organ Weights

In the duodenum there was no significant differences in villi height or crypt depth between the SAD and ED fed pullets (Table 5). In the jejunum, there were significant differences in the crypt depth at 8, 16, and 20 wk of age ($P \leq 0.05$) with the ED-fed pullets having greater crypt depths than the SAD pullets. Also, in the jejunum there was a significant difference ($P = 0.05$) in the villi height at 16 wk (1580.0 μm and 1443.4 μm for the ED and SAD, respectively). In the ileum, villi height was significantly greater at 16 and 20 wk of age ($P < 0.02$) in the SAD pullets. Jejunum villi height to crypt depth ratio was significantly different ($P < 0.04$) at 8, 16, and 20 wk of age with those pullets fed SAD having a greater ratio than those fed ED (Table 6).

Crop (8 and 12 wk), liver (8, 12, and 20 wk), and ileum (8, 16, and 20 wk) weights as a percentage of BW were significantly different ($P < 0.05$) between the treatments (Table 7). The pullets fed on the SAD program had greater liver, crop, and ileum weights as a percentage of BW than the ED fed pullets.

DISCUSSION

The results from this current research indicated that there are significant benefits to feeding broiler breeder pullets a low-density high fiber diet containing large grain particles or whole grains on an ED feeding program. Providing feed each day improved flock uniformity in rearing as well as allowed the ED fed pullets to achieve target body weight before the SAD pullets at the time of photostimulation. The pullets reared on the ED feeding program had greater overall egg weights and eggshell quality during the lay phase of this experiment. The reasons for this are not well understood. Possibly, the increase in villi height in the jejunum and ileum at 16 and 20 wk in the small intestine of the pullets could explain these results. Perhaps the ED pullets were able to better absorb and utilize nutrients at critical times during development of the intestine leading to more efficient weight gain, medullary bone development and reproductive tract development than the SAD fed

Table 5. Histological analysis data as affected by the feeding programs skip-a-day and every-day feeding (SAD and ED) at 8, 12, 16, and 20 weeks. Each value represents the mean of the villus height and crypt depth of the pullet.

Treatment	WK	Doudenum villi	Doudenum crypt	Jejunum villi	Jejunum crypt	Ileum villi	Ileum crypt
SAD ^c	8	1864.0 ^a	188.7 ^a	1389.0 ^a	114.1 ^a	1080.5 ^a	135.5 ^a
ED ^d		1873.1 ^a	193.6 ^a	1394.6 ^a	173.9 ^b	1139.3 ^a	131.0 ^a
SAD ^c	12	2037.7 ^a	132.6 ^a	1410.0 ^a	133.7 ^a	1010.3 ^a	115.6 ^a
ED ^d		1937.0 ^a	132.4 ^a	1313.0 ^a	138.8 ^a	963.4 ^a	111.6 ^a
SAD ^c	16	2041.4 ^a	147.9 ^a	1443.4 ^a	120.1 ^a	1111.1 ^a	134.3 ^a
ED ^d		2060.0 ^a	147.5 ^a	1580.0 ^b	139.4 ^a	1005.3 ^b	119.7 ^a
SAD ^c	20	2071.9 ^a	160.1 ^a	1560.6 ^a	115.0 ^a	1125.2 ^a	131.8 ^a
ED ^d		2015.3 ^a	141.6 ^a	1570.0 ^a	156.9 ^b	1001.9 ^b	122.1 ^a

^{a-b}Treatments significant within period ($P < 0.05$).

^cSAD = Skip-a-day feeding program.

^dED = Every-day feeding program.

Each value represents the mean of the villus height and crypt depth of the pullet. Mean for different treatments with no common superscript (a-b) are significantly different ($P < 0.05$). No superscript means no significant differences among treatments.

Table 6. Histological data as affected by the feeding programs skip-a-day and every-day feeding (SAD and ED) at 8, 12, 16, and 20 weeks.

Treatment	WK	Doudenum	Jejunum	Ileum
SAD ^c	8	10.4 ^a	13.3 ^a	8.9 ^a
ED ^d		10.1 ^a	8.3 ^b	9.1 ^a
SAD ^c	12	16.1 ^a	11.2 ^a	9.3 ^a
ED ^d		15.1 ^a	10.5 ^a	9.0 ^a
SAD ^c	16	15.2 ^a	13.5 ^a	8.7 ^a
ED ^d		14.2 ^a	11.5 ^b	8.9 ^a
SAD ^c	20	13.7 ^a	14.1 ^a	9.0 ^a
ED ^d		15.3 ^a	11.0 ^b	8.7 ^a

^{a-b}Treatments significant within period ($P < 0.05$).

^cSAD = Skip-a-day feeding program.

^dED = Every-day feeding program.

Each value represents the mean ratio of the villus height to crypt depth expressed as a percentage. Percentage for different treatments with no common superscript (a-b) are significantly different ($P < 0.05$). No superscript means no significant differences among treatments.

pullets. Future research should be conducted to better understand the impact of feeding methods on intestinal development and nutrient utilization. The SAD fed birds had a larger overall digestive tract relative to body weight, and perhaps the larger digestive tract developed to accommodate the large bolus of feed they received on the feed day.

Table 7. Necropsy data as affected by the feeding programs skip-a-day and every-day feeding (SAD and ED) at 8, 12, 16, and 20 weeks. Each value represents the mean of the organ weight expressed as a percentage of the body weight of the pullet.

Treatment	WK	Crop	Liver	Ileum
SAD ^c	8	0.713 ^a	1.893 ^a	0.818 ^a
ED ^d		0.523 ^b	1.660 ^b	0.690 ^b
SAD ^c	12	0.635 ^a	1.530 ^a	0.594 ^a
ED ^d		0.520 ^b	1.300 ^b	0.521 ^a
SAD ^c	16	0.426 ^a	1.136 ^a	0.486 ^a
ED ^d		0.361 ^a	1.125 ^a	0.367 ^b
SAD ^c	20	0.456 ^a	1.524 ^a	0.461 ^a
ED ^d		0.398 ^a	1.119 ^b	0.337 ^b

^{a-b}Treatments significant within period ($P < 0.05$).

^cSAD = Skip-a-day feeding program.

^dED = Every-day feeding program.

Each value represents the mean of the organ weight expressed as a percentage of the body weight of the pullet. Percentage for different treatments with no common superscript (a-b) are significantly different ($P < 0.05$). No superscript means no significant differences among treatments.

It should be noted that further research should also be conducted on feeder types and their ability to aid in the delivery of feed on an ED basis. This study was based on the impacts of delivery method on pullet development and reproductive performance. Feeding equipment type was not used as an evaluation parameter for this study. However, this research can aid in the implementation of ED feeding due to the current use of older types of chain feeders still in use in the US, that can only deliver feed at approximately 18 to 27 m/min in houses that range from 91 to 153 m long (Wilson, 2003). The attraction to these chain feeders is their longevity and ease of use. Pan feeders offer more rapid delivery through the house but can be more mechanically complex and expensive. More modern chain feeders have variable speed control settings that can distribute feed to a flock at 36 m/min (van de Sluis, 2011). The ability to feed flocks on an ED basis must take into consideration the feed formulation as well as feeding equipment.

Body Weight, Uniformity, and Intestinal Morphology

Extensive research with whole oats indicates they offer poultry approximately 2,756 kcal/kg (Ahiew et al, 2018) and nonstarch polysaccharides comprise 300 g/kg of whole oats due to the hull (Knudsen and Bach, 1997). This low protein and bulky feedstuff increased the feed volume and improved feed distribution providing more opportunity for birds to eat than a standard concentrated diet. In our study both treatment groups received the same bulky diet increasing the opportunity for the birds to feed. In addition to the whole oats, we used wheat middlings to increase the fiber content of this diet. High fiber diets have proven to modulate intestinal morphology of poultry (Han et al., 2017; Tejada and Kim, 2021). The increased villus height seen in the pullets on the ED treatment increased the overall surface area of the small intestine which could explain the greater nutrient absorption and utilization. Enzyme activity is greatest in the jejunum and the enzymes are located in the epithelial cells of the villi which are important for the last steps of digestion (Denbow, 2015). Also, while not significant there were

consistently smaller crypts in the ileum of the ED fed pullets. A decrease in crypt depth is correlated to an improvement in digestion (Seyyedini and Nazem, 2017).

ED feeding also decreased the time pullets were without feed. Increasing fasting time has shown to increase gut permeability (Gilani et al., 2017). This means that the intestinal walls become more easily permeable to things such as bacteria and toxins which can cause inflammatory reactions in digestive organs such as the liver (Bischoff et al., 2014). Fasting also increases intestinal sloughing and decrease villi height in as little as 24 h (Yamauchi et al., 1997). These factors together can negatively impact nutrient utilization. This is perhaps why the ED fed pullet gains more weight on the same amount of feed as the SAD fed pullets (BW and uniformity). However, the increase in the villus height to crypt depth ratio in the SAD fed pullets should be noted. An increase in this ratio is an important reflection of the improvement of absorption and digestion of nutrients (Hou et al., 2010; Hou et al., 2012; Yao et al., 2012). Perhaps the SAD fed pullets directed their nutrient allocations to building a larger digestive tract instead of bone and muscle to process the large bolus of feed on the feed day. Nutrients could also have been allocated to the digestive tract for repairs from intestinal sloughing on the off-feed days as well. This can be indirectly seen in the relative percentage of body weight of the digestive tract of the SAD pullets when compared to the ED fed pullets. High dietary fibers have been shown to have a harsh effect on the intestinal walls which leads to nutrient loss (Leterme et al., 1998). Perhaps such a large bolus of high fiber feed on the SAD fed pullets impacted breakage and cell loss in the intestines as well, leading to the SAD pullets being under weight and slower to sexually mature.

Productivity and Eggshell Quality

Several factors impact the successful stimulation of broiler breeder pullets into lay and production of high-quality eggs. Achieving proper BW prior to the time of photostimulation is important to optimum reproductive performance. Researchers report that pullets fed on an ED basis started to lay at a younger age and had increased egg production (Katanbaf et al., 1989; Wilson et al., 1989; de Beer and Coon, 2007). This study agrees with these reports that pullets fed ED during rearing achieved first egg (sexual maturity) one week prior to the pullets fed SAD during rearing.

The development of the reproductive tract during rearing and at time of stimulation is critical for broiler breeders. However, equally as critical can be the development of bones and more specifically their medullary bones that act as a reservoir for calcium for birds during lay (Prondvia and Stein, 2014). During the rearing phase the pullet is developing muscle, bones, feathers, and their reproductive tract. Nutrition and the utilization of nutrients are critical for all aspects of development. Bone formation requires nutrients such as

calcium, protein, magnesium, phosphorus, vitamin D, potassium, and fluoride (Palacios, 2006). In this study ED fed pullets had longer villi, greater villi height to crypt depth ratios, and higher and more uniform body weights, suggesting that better intestinal morphology of the ED fed pullets allowed for improved nutrient utilization as well as bone and reproductive tract development. We see the impacts of this nutrient utilization in improved shell quality measured by specific gravity of the ED versus the SAD fed pullets. If the pullets fed ED were able to deposit and build more dense medullary bone this is perhaps an explanation for the better overall eggshell quality when compared to the SAD fed pullets. Bone density and mineral content of the bones of ED and SAD pullets and hens should be evaluated in future studies to confirm this observation.

CONCLUSION

Feed restriction of broiler breeders is necessary due to genetic selection for increased growth of broilers; however, our use of high-density diets has made feed restriction of broiler breeders challenging. These feed restriction programs are critical for BW management, flock uniformity, and reproductive performance. The traditional SAD feed restriction program using these high-density feeds can lead to welfare issues and underperformance. In this study, we showed an improvement in achieving first egg, intestinal development and eggshell quality in hens fed a low-density high fiber diet ED as a pullet. In addition, ED fed pullets had increased BW at time of stimulation, improved flock uniformity, overall egg weight, overall specific gravity, and encouraged longer and more robust villi compared to the SAD fed pullets. We conclude that the differences in these parameters mentioned are attributed to the method of delivery (SAD or ED) and the physiological impact on the bird utilizing a low-density high fiber diet.

DISCLOSURES

Please know that I have no conflicts of interest in publishing this work.

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