

In pursuit of a better broiler: welfare and productivity of slower-growing broiler breeders during lay

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ABSTRACT Current commercial strains of broiler breeders display reproductive dysregulation when fed to satiety, but they can achieve optimal hatching egg production under feed restriction. However, chronic feed restriction in broiler breeders is a welfare concern due to physiological and behavioral signs of hunger, lack of satiety, and frustrated feeding motivation. The purpose of this study was to assess the welfare and productivity of slower-growing broiler breeders during lay. A total of 336 broiler breeders from 5 strains of slower-growing broiler breeders (3 female strains: 100 hens per strain, and 2 male strains: 12 and 24 roosters per strain) were kept in 12 identical pens throughout lay, 4 pens per combination of roosters and hens: A hens with Y roosters, B hens with Y roosters, and C hens with X roosters. According to guidelines, strain B and C hens and X roosters were slower growing strains and strain A hens and Y roosters were intermediate growing strains. Egg production was recorded daily, and settable eggs laid at 30, 40,

and 50 wk of age were incubated to hatch. Growth rate, feed and water intake, and welfare indicators (feeding motivation, behavior, and physical assessment: feather coverage, foot and leg health, and keel bone status) were recorded during lay. Additionally, a subsample of 5 hens per pen was dissected for anatomical analyses. Laying rate started and peaked earlier in B hens than in A hens and remained above 70% in both strains, yielding high cumulative egg production (>165 eggs/hen) until 53 wk of age. Until 50 wk of age, fertility and hatched of fertile was high in slower growing broiler breeders, on average, above 95 and 80%, respectively. Compared to A hens, B and C hens had better feather coverage, lower feeding motivation, and lower daily water and feed intake. Results of this study suggest that slower growing broiler breeders show reduced signs of poor welfare and improved productivity during lay although susceptibility to obesity-related problems on laying rate may be strain-specific.

Key words: hunger, frustration, egg production, obesity, efficiency

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INTRODUCTION

Selection for fast growth in broiler chickens has led to welfare and production problems in broiler breeders (Renema and Robinson, 2004). Because of their potential for high feed intake, broiler breeders fed to satiety develop excess weight and fat accumulation, both of which are common risk factors for high mortality, metabolic disorders or other health difficulties, poor laying rate, and breeding problems (Katanbaf et al., 1989a,b; Bruggeman et al., 1999; Heck et al., 2004). Excessive body weight is linked with dysfunctional ovaries resulting in poor laying rate in broiler breeder hens (de Jong and Guémené, 2011; van Krimpen and de Jong, 2014)

and poor sperm quality and low breeding activity in broiler breeder roosters (Carter et al., 1972; Hocking and Bernard, 2000; Sarabia Frago et al., 2013) that, in turn, lead to low fertility and hatchability of settable eggs. Therefore, controlling early growth rate is necessary for broiler breeders to achieve optimal reproductive performance during lay.

Feed restriction is a common on-farm practice to reduce health and reproductive problems related to high body weight and excessive fat content in broiler breeders (Savory et al., 1993; Hocking et al., 2001; Chen et al., 2006). However, chronic feed restriction raises welfare concerns because feed-restricted broiler breeders commonly show physiological and behavioral signs of distress and frustrated feeding motivation, particularly during rearing (D'Eath et al., 2009; de Jong and Guémené, 2011; Tolkamp and D'Eath, 2016). To reduce hunger, research conducted on conventional, fast-growing strains of broiler breeders has focused on designing alternative feeding strategies that either increase feed allotment (e.g., qualitative and non-daily quantitative

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feed restriction) and/or lower feeding motivation through the addition of appetitive suppressants (Sandilands et al., 2005, 2006; Nielsen et al., 2011; Morrissey et al., 2014a,b). Nonetheless, conventional broiler breeders still display signs of chronic hunger and distress under these feeding strategies (Arrazola et al., 2019a, 2020a,b; Aranibar et al., 2020; Tahamtani et al., 2020).

Alternative strains of broiler breeders are commercially available, and strains with slower growth rates may provide a solution to the problem of chronic feed restriction (Jones et al., 2004; Dawkins and Layton, 2012). During rearing, slower and intermediate growing broiler breeders showed fewer signs of hunger, lack of satiety, frustrated feeding motivation, and distress due to feed restriction (de Jong et al., 2003; Arrazola and Torrey, 2021). During lay, performance objectives for slower growing broiler breeders indicate that they can achieve high reproductive performance (e.g., high and persistent laying rate at a high

hatchability) at a lower level of feed restriction level (Aviagen, 2018a; Hubbard, 2019; Sasso 2019). In conventional broiler breeders, laying persistency decreases soon after hens reach the peak in egg production (e.g., Ross 308 [van Emous et al., 2015a; Arrazola et al., 2019b], Ross 708 [van der Klein et al., 2018], and Cobb 500 [Arabinar et al., 2020; Oviedo-Rodon et al., 2021]), and hatchability decreases in settable eggs laid after 45 to 50 wk of age (Igbal et al., 2016; Aviagen, 2021a,b; Cobb, 2020). Hence, using slower growing broiler breeders may not only alleviate welfare concerns about chronic feed restriction but also lead to a more efficient and sustainable production system.

Empirical data on the welfare and performance of slower growing broiler breeders is very limited. Slower growing broiler breeders do not require as severe of feed restriction as do conventional broiler breeders (Jones et al., 2004; Arrazola and Torrey, 2021), and results reported in Heck et al. (2004) suggest that alternative strains of slower growing broiler hens can achieve optimal egg production during lay. Yet, little is known about the feasibility of using slower growing broiler breeders for broiler chick production. Thus, the objective of this project was to examine welfare indicators, performance, and efficiency outcomes of slower growing broiler breeder strains (slower and intermediate growing strains of hens and roosters) during lay. Compared to faster growing broiler breeders, slower growing broiler breeders were hypothesized to have better welfare, health, and reproductive performance as indicated by lower feeding motivation, better feather coverage, lower prevalence and severity of foot lesions and hock burns, and higher laying persistency and hatchability. Although direct comparisons with conventional broiler breeders were not made in the study reported here, results were descriptively compared with those from previous

studies on conventional broiler breeders subjected to alternative feeding strategies kept in the same experimental housing and using similar methods (Morrissey et al., 2014b; Arrazola et al., 2019b).

MATERIALS AND METHODS

All procedures used in this experiment were approved by the University of Guelph's Animal Care Committee (AUP # 3746) and were in accordance with the guidelines outlined by the Canadian Council for Animal Care (NFACC, 2016).

Experimental Design, Housing, and Management

A total of 336 broiler breeders from 5 strains of slower growing broiler breeders (3 female strains and 2 male strains) were housed at the research station of the University of Guelph from January 2019 to September 2019 during lay. Three female strains and 2 male strains were donated courtesy of an anonymous breeding company at 1 d of age. Female strains were strain A (100 hens), strain B (100 hens), and strain C (100 hens), and male strains were strain X (12 roosters) and strain Y (24 roosters). According to breeder guidelines, strain B and C hens and strain X roosters were slow growing strains, and strain A hens and Y roosters were intermediate growing strains. The experimental design was a randomized block design with 3 treatments (combination of broiler breeder hens and roosters) with four replicates per treatment.

Chicks were vaccinated against Marek's disease, coccidiosis, and infectious bronchitis at the hatchery based on local recommendations and the health program of the research facility. Beaks of females and males were left intact, and males received toe trimming at the hatchery. Upon arrival, all chicks from the same strain were placed in one floor pen (1.63 m wide × 1.22 m deep × 0.82 m height). At 13 d of age, females were split into 25-chick groups and males into 10-chick groups, segregated by strain (except for X chicks with only 2 groups). Chicks from each strain were reared in identical floor pens (0.82 m wide × 1.22 m deep × 0.82 m height) until 10 wk of age and then, moved to identical floor pens (2.36 m wide × 1.83 m deep; female pens: 9.3 pullets/m², and male pens: 2.3 cockerels/m²) until 21 wk of age. Pens were managed according to breeding company guidelines, and conditions were the same for all strains except for strain-specific feed allotment. Chicks were fed ad libitum until 2 wk of age for males and strain A females, and until 4 wk of age for strains B and C. Daily feed allotment for each strain was calculated to follow strain-specific growth curves according to breeder guidelines. During rearing, pullets and cockerels were fed daily following a commercial feeding program with 3-stage diets (Broiler breeder program, Floradale Feed, Floradale, ON, Canada) and water was provided ad libitum. Pullets were raised at 10 lux for 8L:16D from wk 2 to 19.

Then, the light program switched to 30 lux at 10L:14D from wk 19 to 20 and to 30 lux at 12L:12D from wk 20 to 21. See [Arrazola and Torrey \(2021\)](#) for further detail about the rearing phase.

At 22 wk of age, hens were moved in groups of 25, segregated by strain, into one of 12 floor pens (4 pens per strain; 3.7 m wide × 2.5 m deep, 3.1 pullets/m²) with wood shavings and mineral pecking blocks (PECK-stones, Vilofoss, Lucknow, ON, Canada). The pens were 9.25 m², and 60% of area was plastic slat at 0.45 m above the scratching area (remaining 40%). Pens were equipped with 2 trough feeders with male exclusion grids (13 cm wide × 152 cm long × 5 cm deep each, 12.2 cm/hens), 1 elevated round feeder for males (25 cm/cock-erel), 2 drinker lines (14 nipples, 1 nipple per 2 birds), and 10 nest boxes (28 cm deep × 28 cm wide × 59 cm high).

Three roosters were introduced to each pen. Strain Y roosters were housed with A and B hens, and X roosters with C hens. Each combination of roosters and hens were kept in 4 identical pens which were equally distributed between 2 rooms. Hens and roosters were feed-restricted to follow specific growth curves for each strain, and daily feed intake for hens was also adjusted based on laying rate. Hens and roosters were fed daily following a commercial feeding program with 2-stage feeding program (Broiler breeder program: a boiler breeder layer 1 diet from 22 to 45 woa and a broiler breeder layer 2 diet from 46 to 53 woa, Floradale Feed, Floradale, Ontario). Water was provided ad libitum during lay. Room remained at 21°C during lay, and the light program was 30 lux at 12L:12D until 53 wk of age using white LED bulbs. Lights came on at 0900 hours, and birds were manually fed approximately 30 min later. Birds were checked twice per day, and mortality was recorded as it occurred.

Data Collection

Body Weight and Body Weight Uniformity Hens and roosters were weighed individually at 21 wk of age and every 2 wk from 39 to 53 wk of age, and in groups at 26 and 36 wk of age. Body weight uniformity was calculated using the coefficient of variation (**CV**) of each pen by dividing the standard deviation by the average body weight.

Feed and Water Intake Feed allotment was weighed every day for each pen and adjusted for mortality as it occurred. The remaining feed in the feeders was weighed at the end of lay to calculate the cumulative feed intake (including the cumulative feed intake during rearing [in [Arrazola and Torrey, 2021](#)]). Feed efficiency was calculated at 53 wk of age using the feed conversion ratio (**FCR**) of each pen by dividing the average body weight gain by the cumulative feed intake. During lay, a water intake test was performed to estimate daily water intake per bird at 44, 47, and 50 wk of age. Two 3-gallon (11.36 L) hanging waterers (4 nipples per waterer; Farm Tuff, ON, Canada), previously used during early rearing, were

placed per pen for 2 consecutive days. The first day was a 24 h habituation period before the test started. After the 24 h period, nipple drinker lines were raised so water intake could only be from the hanging waterers. Waterers were weighed at 24 and 48 h after placement. Water intake per bird was calculated by subtracting the initial water weight (after 24 h) minus the final weight (after 48 h) and dividing by the number of birds per pen.

Egg Production, Egg Weight and Egg Weight Uniformity, Fertility, and Hatchability Eggs were collected daily from 19 to 53 wk of age after hens were fed in the morning. Egg production was categorized into 2 phases: early lay (19–29 weeks of age) and after peak (30–53 wk of age). Eggs were individually weighed biweekly from wk 39 to 53, and in groups before setting eggs for incubation (at wk 40 and 50) in the federally inspected hatchery located at the research station. For incubation purposes, 1,350 (450 per strain), 1,440 (120 eggs per pen [480 eggs per strain]), and 1,440 (120 eggs per pen [480 eggs per strain]) settable eggs were collected at 30, 40, and 50 wk of age, respectively. *Settable eggs* were defined as clean eggs (i.e., eggs without fecal material covering an area greater than 0.25 cm²), heavier than 52 g, not double-yolked, cracked, or warm at the time of egg collection. Settable eggs laid at 30 wk of age were combined by strain for incubation; therefore, data from this week of age were not included for statistical analyses. Settable eggs laid at 40 and 50 wk of age were stored by pen and date of collection in a cooler at 15.5°C for less than 7 d before incubation. No disinfection procedure or in ovo vaccination was applied to settable eggs. Settable eggs laid at 40 and 50 wk of age were moved to the setter in compartments separated by parent pen, controlling for location within the setter among strains. Eggs were incubated at 37.5°C and 55% relative humidity at 24 turns per day. After 18 d of incubation, fertile eggs were transferred to the hatcher by pen for 4 d at 37.5°C and 75% relative humidity. Discarded eggs were cracked to assess fertility based on germinal disk criterion ([Watt et al., 1993](#)) and embryo mortality based on embryo development. Fertility was calculated by dividing the number of fertile eggs by the number of settable eggs. Hatchability was determined at 21.5 d of incubation, and the remaining (unhatched) eggs were also cracked to assess fertility and embryo mortality. Hatchability was calculated by dividing the number of live chicks that successfully left their shell by the number of settable eggs, and hatch of fertile was calculated by dividing the number of chicks by the number of fertile eggs. Chicks were weighed in parent pen groups and vent-sexed upon hatching.

Health and Welfare Indicators All broiler breeders were scored individually for pododermatitis (e.g., foot lesions and foot burns) and feather coverage after being weighed at 41, 45, 49, and 53 wk of age. Foot lesions and hock burns were defined as tissue damage, bleeding, coagulated injuries, inflammation, necrosis and/or haematoma of the foot and toe pad(s) and hock(s), respectively. Birds were assessed for foot lesions and hock burns using a 5-scale scoring system sensitive to

prevalence and severity of foot lesions and hock burns (Arrazola and Torrey, 2021). Body feather coverage was scored using a 6-scale scoring system for each given body area. Six body areas were assessed including head, neck, back, vent, wings, and tail based on Morrissey et al. (2014a) and Arrazola et al. (2019a). Breast and leg areas were excluded because of the difficulty distinguishing between feather pecking and abrasive damage (Bilcik and Keeling, 2000). Each body part was assessed using a 6-point scoring system where score 0 indicated fully covered and score 5 referred to feather loss equal to or greater than 50% including skin lesion (s). Results from the 6 areas were summed together to result in a total body feather coverage score from 0 to 30, with 30 being the worst feather coverage condition.

A random subsample of 10 hens per pen was individually palpated for keel bone fractures and deviations at 52 wk of age. Keel bone deviations were defined as abnormal curvature of the keel bone, either ventral or longitudinal, and keel bone fractures were identified as the presence of bony callus on the ventral or lateral surfaces of keel bone (Casey-Trott, 2016; Fawcett et al., 2020). Hens were scored separately by 2 researchers (T. M.W. and L.C.) blind to strain for the presence and severity of keel bone fractures and deviations using a 4-scale scoring (0: none, 1: mild, 2: moderate, and 3: severe) previously used in Casey-Trott 2016.

Feeding motivation for hens and roosters was assessed using feed intake tests at 40, 44, 48 and 52 wk of age at their regular feeding time (Arrazola et al., 2019b). For hens, feed intake was measured 1 h after being fed their regular feed allotment and using their usual grid feeders. Before starting the feed intake test, researchers recorded and weighed any remaining feed from the previous day. Feeders (plus feed) were weighed before and after the feed intake test. Total feed intake was divided by the number of hens and the relative feed intake to body weight was calculated by dividing the average feed intake during the test by average body weight. For roosters, researchers recorded how long it took them to consume all the feed in their feeder (via live observation). Then, feeding rate was calculated by dividing feed allotment by feeding time.

Postprandial behavior was observed 30 min after filling feeders with the usual feed allotment for hens and roosters at 42 wk of age. Camcorders and tripods were placed in front of the floor pens after hens and roosters were fed. Video recordings started 30 min after regular feed allocation and lasted for 15 min. One researcher observed the behavior of the hens and the roosters separately using instantaneous group scan sampling every 15 s for 5 min starting after 10 min of habituation to the recording equipment placed in front of their pens. Recordings were observed for the following mutually exclusive behaviors: feeding, drinking, foraging (scratching and litter pecking), redirected oral behavior (object and feather pecking), maintenance behavior (preening and dust-bathing), locomotion (running and walking), resting (sitting, standing, or perching while inactive), pre-laying (sitting with ruffled feathers and tail up), mating, and others. Location was recorded as

nest box, slat, and scratching area. The proportion of hens and roosters performing each behavior and location was calculated by dividing the number of birds displaying each behavior by the number of birds for which the observer could assess their behavior. Behavioral data were averaged per strain/sex and pen.

Anatomical Traits At 53 woa, a subsample of 5 hens per pen that were within 5% of the average body weight of their pen, were killed via cervical dislocation for dissection. Whole carcasses, and then liver, fat pad, and the reproductive system (i.e., oviduct and ovary) were collected and weighed. The presence of fatty liver (i.e., at least 50% of the total hepatic surface showed discoloration) and the presence of an immature egg in the oviduct were recorded in situ as yes/no in agreement between 2 researchers. Ovaries and keel bones were collected and kept in a cooler for further analyses. On the following day, follicles were removed from the ovary and placed on a grid surface to count the number of atretic follicles, large yellow follicles (LYF; >10 mm), and small yellow follicles (SYF; 10–5 mm) (Renema and Robinson, 2004). Then, stroma of the ovary and the total number of LYF and SYF were weighed separately. Keel bones were observed for the presence of keel bone fractures and deviations as previously defined. Researchers recorded the number and location of keel bone fractures and scored the severity of keel bone deviations as none, mild (minor bends), moderate (pronounced deviations such as minor s-shape), and severe (extreme deviations including rotated, curved, and crushed; Wilkins et al., 2004; Casey-Trott, 2016).

Statistical Analyses

Effect of the strain on the performance outcomes and welfare indicators was analyzed separately by sex using generalized linear mixed models in SAS Ver. 9.4 (SAS Institute, Cary, NC). The degree of significance was set for probability values (P) lower than 0.05 and tendency for probability values equal to or lower than 0.10.

$$Y = \beta X + bZ + \varepsilon$$

Data were analyzed by sex and strain, age and their interaction were included as fixed effects (X) for each model. Room, pen, and pen location within the room were included in the covariance structure as random effects (Z). Age was fit into a repeated structure with pen as subject, and treatment as group. Pairwise comparisons between strains were adjusted for multiple comparisons using the Tukey test. Orthogonal regressions analyzed the effect of age into a linear, quadratic, cubic, and lack of fit response. Model assumptions were assessed using a scatterplot of studentized residuals, linear predictor for linearity, and a Shapiro-Wilk test for normality. The Gaussian distribution was used as the default distribution, but data were transformed if the assumption for linearity

and normality was not met. The prevalence of health problems (presence of keel bone fracture, keel bone deviations, and fatty liver) and score data (foot and leg health scores, and keel bone palpation) were analysed using the binomial and multinomial distribution, respectively.

RESULTS

From 21 to 53 wk of age, mortality was below 2% for hens (A: 1.7%, B: 0.2%, and C: 0.5%) and 1% for roosters (X: 0.7%, and Y: 0.6%)

Body Weight and Body Weight Uniformity

The growth curve of hens differed among strains during lay (Figure 1; $F_{20,90} = 32.82$, $P < 0.001$). Strain A hens grew faster than B and C during lay resulting in A hens being heavier than B (Table 1; $t_{6.3} = 29.86$, $P < 0.001$) and C (Table 1; $t_9 = 15.6$, $P < 0.001$) at 53 wk of age. At this age, the B were also lighter than the C hens (Table 1; $t_9 = 3.1$, $P = 0.03$). Male strains tended to show differential growth rate during lay ($F_{10,100} = 1.91$, $P = 0.05$), and X tended to have a higher growth curve than Y during lay (Figure 1). The CV of body weight tended to be affected by strain of slower growing broiler breeder hens ($F_{2,9} = 3.17$, $P = 0.09$) and roosters ($F_{1,10} = 7.07$, $P = 0.024$). The CV of body weight tended to be lower in B ($7.6 \pm 0.8\%$) than in C hens ($10.5 \pm 0.8\%$; $t_9 = 2.51$, $P = 0.08$) and was lower in Y ($8.0 \pm 1.0\%$) than X roosters ($12.7 \pm 1.5\%$; $t_{10} = 2.66$, $P = 0.024$).

Egg Production, Egg Weight and Egg Weight Uniformity, Fertility, and Hatchability

Figure 2 shows that laying rate differed among strains during early lay ($F_{20,90} = 9.26$, $P < 0.001$), and tended

to differ after 30 wk of age ($F_{2,9} = 4.1$, $P = 0.05$). Laying rate was lower for A hens compared to B hens at 22 ($t_{27.5} = 7.03$, $P < 0.001$), 23 ($t_{27.5} = 6.01$, $P < 0.0001$), and 24 wk of age ($t_{27.5} = 4.62$, $P = 0.005$), and compared to C hens at 23 wk of age ($t_{27.5} = 4.26$, $P = 0.017$). Laying rate tended to be lower after 30 wk of age in C hens ($56.2 \pm 5.9\%$) compared to A hens ($79.1 \pm 5.9\%$; $t_9 = 2.74$, $P = 0.05$). Strain A and B hens had higher cumulative egg production by 53 wk of age than C hens (Table 2), although differences were not significant ($F_{2,10.2} = 0.57$, $P = 0.67$) due to high variation in cumulative egg production among C hen pens (cumulative egg production in each C hen pen was: 88.1, 106.4, 151.9, and 170.9 eggs/hen). During mid lay, hen strain affected mean settable egg weight ($F_{2,9.0} = 16.0$, $P = 0.001$) without differences in the CV of settable egg weight ($F_{2,9.0} = 1.3$, $P = 0.32$). Strain A hens laid heavier settable eggs (63.2 ± 0.5 g) than B (60.3 ± 0.5 g; $t_{9.0} = 4.49$, $P = 0.004$) and C hens (59.8 ± 0.5 g; $t_{9.0} = 5.22$, $P = 0.001$) during mid lay.

Fertility of settable eggs was above 95% from 40 to 50 wk of age without differences among the 3 combinations of slower growing broiler breeders over time ($F_{2,8.3} = 0.11$, $P = 0.90$). Hatchability of settable eggs laid at 30 wk of age was 87.6, 84.2, and 69.8% for A hens with Y roosters, B hens with Y roosters, and C hens with Y roosters, respectively. Hatchability of eggs laid at 40 and 50 wk of age did not differ significantly among strains (Table 2; $F_{2,8.3} = 0.49$, $P = 0.63$). Hatchability decreased from $85.8 \pm 2.3\%$ at 40 wk of age to $80.8 \pm 2.2\%$ at 50 wk of age ($t_{71.6} = 2.48$, $P = 0.016$) due to lower percentage of hatched of fertile ($F_{1,71.6} = 5.86$, $P = 0.018$) without an age effect on fertility ($F_{1,8.7} = 0.60$, $P = 0.46$). Strain A hens laid heavier hatching eggs than B and C hens at 40 and 50 wk of age (Table 2; $F_{2,8.0} = 18.62$, $P = 0.001$), resulting in heavier hatching weights of AY chicks than chicks from the other 2 combinations of broiler breeders (Table 2; $F_{2,8.3} = 11.87$, $P = 0.004$).

Feed and Water Intake

The daily feed intake of broiler breeder hens and roosters is illustrated in Figure 3. Daily feed allotment increased weekly until 24 wk of age for B, 26 wk of age for C, and 28 wk of age for A hens according to peak of laying rate for each strain. Afterward, daily feed allotment decreased based on weekly laying rate post-peak and body weight gain. Hens from all pens of Strains A and B were fed the same strain-specific daily feed allotment per bird throughout the study; however, the daily feed allotment differed between pens of C hens at the end of lay. From 48 to 53 wk of age, the daily feed allotment of 2 pens housing C hens was 6 g per hen lower than recommendations due to excessive body weight (10% above target body weight) and poor laying rate (<50%). Cumulative feed intake per hen until 53 wk of age was higher in A hens than in B and C hens and higher in C than in B hens (Table 1; $F_{2,5.3} = 97.62$,

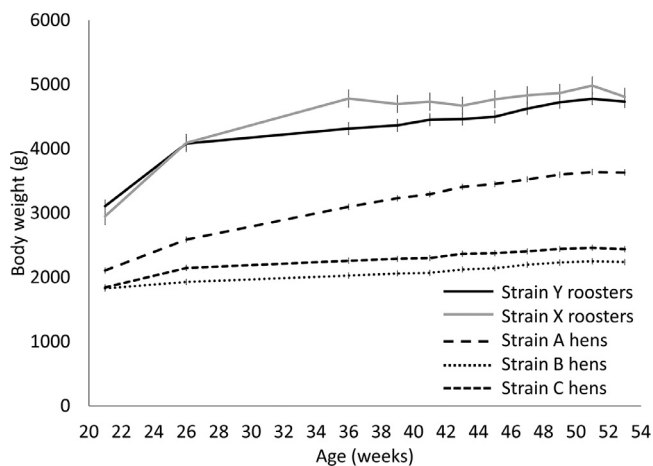


Figure 1. The body weight of slower growing broiler breeders during lay (mean \pm SE). Solid lines refer to 2 strains of roosters (X in gray, and Y in black), and discontinuous lines to 3 strains of hens (A in wide-dashed, B in dotted, and C in narrow-dashed). The growth rate of the broiler breeders differed with age among strains of hens ($P < 0.001$) and a tendency for the rooster strains ($P = 0.05$).

Table 1. The body weight (BW), cumulative feed intake (FI), average daily feed intake (ADFI), and feed conversion ratio (FCR) of slow growing broiler breeders at the end of lay (mean \pm SE).

Performance Measure	Hens			Roosters	
	A	B	C	X	Y
BW (kg) ¹	3.63 \pm 0.04 ^a	2.24 \pm 0.02 ^c	2.44 \pm 0.06 ^b	4.81 \pm 0.11	4.69 \pm 0.21
FI (kg/bird)	43.28 \pm 0.10 ^a	33.72 \pm 0.73 ^b	33.04 \pm 1.41 ^b	38.52 \pm 0.50 [†]	39.64 \pm 0.38 [†]
ADFI ² (g/bird/d)	156.1 \pm 0.1 ^a	117.1 \pm 0.1 ^c	124.2 \pm 0.3 ^b	124.0 \pm 0.0 ^b	133.2 \pm 0.0 ^a
FCR	12.09 \pm 0.32 ^b	15.46 \pm 0.13 ^a	13.84 \pm 0.63 ^{ab}	8.07 \pm 0.36	8.58 \pm 0.29

¹BW at 53 wk of age²Average daily feed intake from 22 to 53 wk of age.^{a-c}Different letters indicate significant mean differences within a row between females and males ($P < 0.05$).^{†-†}Different symbols refer to a tendency for mean difference within a row for male strains ($P < 0.05$).

$P < 0.001$). Roosters had similar daily feed allotment at the onset of lay, but daily feed allotment was decreased over time due to excessive body weight gain, particularly in X males. The cumulative feed intake per rooster until 53 wk of age tended to be lower in X than in Y roosters (Table 1; $F_{1,8,8} = 4.0$, $P = 0.08$).

Results from the water intake test during lay indicate that the daily water intake differed among strains ($F_{2,9} = 5.38$, $P = 0.029$) and age ($F_{2,18} = 11.21$, $P < 0.001$). Strain A hens with Y roosters had higher daily water intake (268.9 \pm 9.1 mL/bird) than B hens with Y roosters (230.3 \pm 9.1 mL/bird; $t_9 = 3.00$, $P = 0.036$) and tended to have higher water intake than C hens with X roosters (234.8 \pm 9.1 mL/bird; $t_9 = 2.65$, $P = 0.06$). Over time, daily water intake decreased from 254.3 \pm 6.5 mL/bird at 44 wk of age to 226.8 \pm 6.5 mL/bird at 50 wk of age ($t_{18} = 4.21$, $P = 0.001$).

Health and Welfare Indicators The prevalence and severity of foot lesions did not differ significantly from 41 to 53 woa, and Table 3 summarizes the average frequency of foot lesion scores in slower-growing broiler breeders during this period. Strain A hens scored higher for the presence and severity of foot lesions than B and

C hens (prevalence: $F_{1,9} = 5.3$, $P = 0.047$, and severity: $F_{1,11} = 7.5$, $P = 0.019$). Overall, the prevalence of foot lesions was 28, 17, and 23% in A, B, and C hens ($F_{2,9} = 3.34$, $P = 0.08$), respectively, and 61.1 and 72.9% in X and Y roosters ($F_{1,10} = 1$, $P = 0.34$), respectively. The severity and prevalence of hock burns was minor for hens (rarely observed) and low for roosters (less than 20%).

The prevalence of keel bone fractures (via palpation) was 20, 17, and 17% in A, B, and C hens, respectively, and the prevalence of keel bone deviations (via palpation) was 7, 20, and 12% in A, B, and C hens, respectively. At 53 wk of age, there were no significant differences among hen strains for keel bone fractures ($F_{2,11} = 0.05$, $P = 0.95$) or deviations ($F_{2,8,9} = 0.80$, $P = 0.48$).

The average feather coverage score of slower growing broiler breeder hens and roosters was low (i.e., good feather coverage) during mid lay (Figure 4). Most of the feather coverage loss was observed on the back (43.5%) and wings (41.2%) of hens and on the neck (43.1%) and tail (38.3%) of roosters. Figure 4 illustrates that the feather coverage worsened with age depending on the hen strain ($F_{4,18} = 2.97$, $P = 0.048$) without differences between rooster strains ($F_{1,10} = 1.33$, $P = 0.28$). The feather coverage of A hens decreased from 41 to 49 wk of age ($t_{18} = 6.05$, $P < 0.001$), whereas B and C hens scored similarly for feather coverage during the same period.

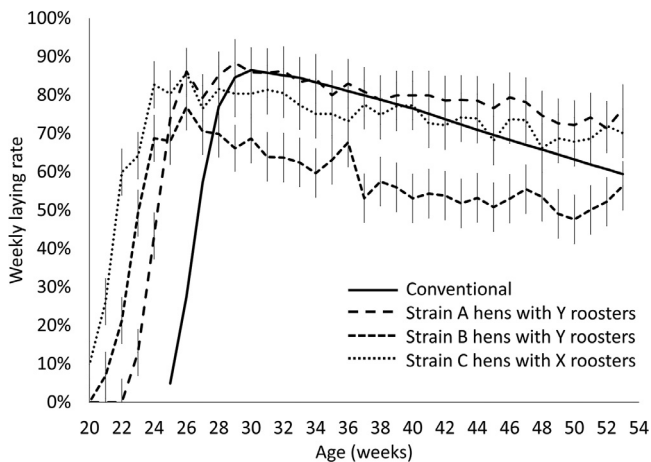


Figure 2. The laying rate of three strains of slower growing broiler breeders during lay (mean \pm SE) compared to a conventional strain of broiler breeders. Discontinuous lines refer to each combination of broiler breeders in this study (A in wide-dashed, B in dotted, and C in narrow-dashed), and the solid line refers to the laying rate of Ross 308 hens according to performance objectives by breeding company (Aviagen, 2021a). The strain of broiler breeder hens affected the laying rate during early lay ($F_{20,90} = 9.26$, $P < 0.0001$) and tended to affect after 30 wk of age ($F_{2,9} = 4.1$, $P = 0.05$).

Table 2. The reproductive performance of slower growing broiler breeders during mid lay (mean \pm SE).

Production Measure	Strain combinations		
	A with Y	B with Y	C with X
Cumulative egg production ¹	165.8 \pm 4.3	164.8 \pm 14.0	129.4 \pm 33.9
Fertility (%) ²	98.8 \pm 0.6	97.3 \pm 0.7	98.1 \pm 0.8
Hatched of Fertile (%) ²	82.1 \pm 3.4	88.4 \pm 3.9	84.7 \pm 3.5
Hatchability (%) ²	81.1 \pm 3.3	86.1 \pm 3.8	82.8 \pm 3.5
Hatching egg weight (g) ²	63.2 \pm 0.4 ^a	60.3 \pm 0.5 ^b	59.8 \pm 0.4 ^b
Live chick weight (g) ²	44.5 \pm 0.4 ^a	41.9 \pm 0.4 ^b	42.4 \pm 0.4 ^b
Percentage of male chicks (%) ²	49.9 \pm 2.1	53.6 \pm 2.3	51.0 \pm 2.2

Female strains: A hens (A), B hens (B), and C hens (C), and male strains: X roosters (X), and Y roosters (Y).

¹Cumulative egg production per hen until 53 wk of age.²Mean values of settable eggs laid at 40 and 50 wk of age incubated to hatch.^{a-b}Different letters indicate significant mean differences within a row ($P < 0.05$).

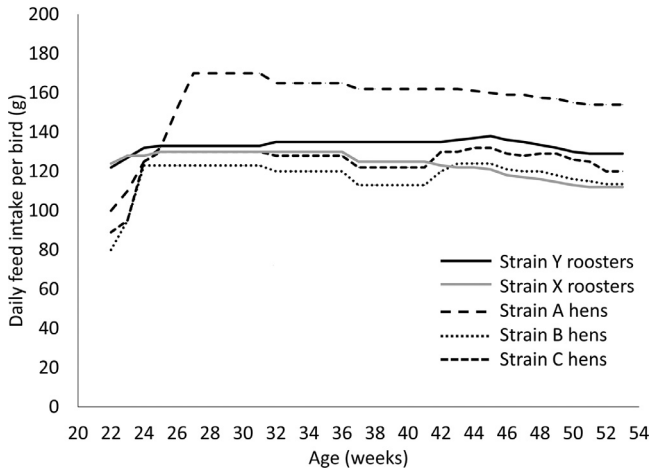


Figure 3. The daily feed allotment per bird of slower growing broiler breeders during lay (mean ± SE). Solid lines refer to 2 strains of roosters (X in gray, and Y in black), and discontinuous lines to 3 strains of hens (A in wide-dashed, B in dotted, and C in narrow-dashed).

The relative feed intake of hens during the feeding tests varied among strains over time ($F_{6,36} = 2.58$, $P = 0.035$). The feeding motivation of B and C hens decreased from 40 to 52 wk of age, whereas the relative feed intake of A hens did not vary significantly over time (Figure 5). From 44 to 53 wk of age, A hens were less likely to have leftover feed the following morning ($22.5 \pm 8.3\%$ of the instances) than the B ($70.0 \pm 8.3\%$ of the instances; $t_{10} = 4.07$, $P = 0.006$) and C hens ($95.0 \pm 8.3\%$ of the instances; $t_{10} = 6.21$, $P < 0.001$). Strain X and Y roosters finished their ration in 39 and 27 min after being fed, respectively; and the feeding rate tended to be higher in Y roosters (5.5 ± 0.5 g per min) than in X roosters (3.8 ± 0.7 g per min; $t_{10} = 2.12$, $P = 0.06$).

Table 4 shows the percentage of hens and roosters performing different behavior patterns, and the percentage of time they spent in different locations 40 min after feeding. Strain affected the percentage of hens observed pre-laying ($F_{2,9} = 5.77$, $P = 0.024$) and performing maintenance behaviors ($F_{2,9} = 3.4$, $P = 0.08$), and the percentage of hens observed on the slats ($F_{2,9} = 6.26$, $P = 0.019$) versus in the nest boxes ($F_{2,9} = 6.42$, $P = 0.018$). Strain A hens spent more time pre-laying than C hens ($t_9 = 3.24$, $P = 0.025$) and tended to spend

Table 3. Average frequency of foot lesion score in slower growing broiler breeder hens ($F_{2,11} = 7.67$, $P = 0.022$) and roosters ($F_{1,11} = 1.06$, $P = 0.33$) by strain during mid lay (41–53 wk of age).

	Hens			Roosters	
	A	B	C	X	Y
Foot lesion score ¹					
0	71.8%	82.0%	78.0%	4%	26.6%
1	17.6%	9.7%	12.5%	17.1%	20.3%
2	4.7%	1.7%	3.4%	2.9%	4.7%
3	5.0%	5%	5.2%	20.0%	20.3%
4	1.0%	1.7%	0.9%	20.0%	28.1%

¹Scores: 0 (absence of foot lesion), 1 (lesion smaller than 25% of footpad area), 2 (lesion equal to or bigger than 25% of footpad area), 3 (lesion(s) smaller than 25% of footpad area with ulceration, crust, or swollen), and (lesion(s) equal to or bigger than 25% of footpad area with ulceration, crust, or swollen).

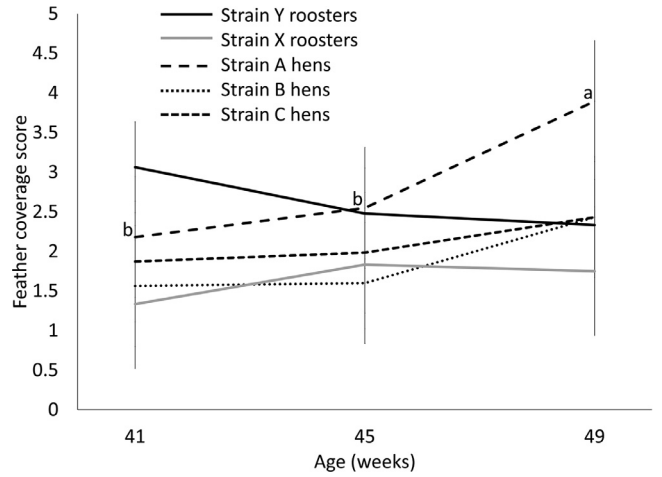


Figure 4. Feather coverage score of slower growing broiler breeders over time during mid lay (mean ± SE). High scores indicate feather coverage loss and presence of skin lesion, being 30 the highest feather coverage score. Solid lines refer to 2 strains of cockerels (X in gray, and Y in black) and discontinuous lines to 3 strains of pullets (A in wide-dashed, B in dotted, and C in narrow-dashed). Different letters indicate significant mean differences between time points for A hens ($P < 0.05$); overall feather coverage in A hens deteriorated over time ($P < 0.01$).

more time pre-laying than B hens ($t_9 = 2.50$, $P = 0.07$). Strain A hens tended to spend more time in maintenance behavior than C hens ($t_9 = 2.56$, $P = 0.07$). A higher percentage of A hens were in the nest boxes compared to B ($t_9 = 2.82$, $P = 0.048$) and C hens ($t_9 = 3.32$, $P = 0.022$). Strain affected the percentage of roosters observed feeding ($F_{1,10} = 6.21$, $P = 0.032$), and X roosters spent more time feeding than Y roosters (Table 4; $t_{10} = 2.49$, $P = 0.032$).

Anatomical Traits The presence of fatty liver tended to be higher in A hens ($60 \pm 12\%$) compared to the combination of B and C hens ($25 \pm 9\%$; $F_{1,7.8} = 4.67$,

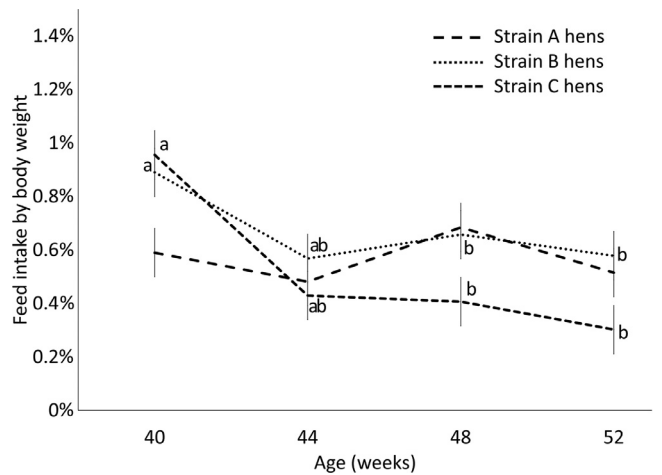


Figure 5. Relative feed intake of slower growing broiler breeder hens on a feed intake test during mid lay (mean ± SE). Feeding motivation was estimated as the feed intake for 1 hour relative to the average body weight. Line patterns indicate the three strains of hens (A in wide-dashed, B in dotted, and C in narrow-dashed). The relative feed intake of slower growing broiler breeder hens differed over time for the B and C hens, and there was a tendency for significant differences among strains ($P = 0.07$). Different letters indicate significant mean differences over time within each strain ($P < 0.05$).

Table 4. Percentage of time that slower-growing broiler breeder hens (Strain A, B, and C) and roosters (Strain X and Y) spent in each behavior and location 30 min after feeding at 42 wk of age (mean \pm SE).

Behavior and Location	Hens			Roosters	
	A	B	C	X	Y
Behaviors¹					
Standing	23.7 \pm 4.5%	28.1 \pm 4.5%	26.7 \pm 4.5%	12.0 \pm 8.0%	29.1 \pm 5.7%
Foraging	13.2 \pm 4.4%	20.3 \pm 4.4%	17.0 \pm 4.4%	30.5 \pm 11.1%	44.0 \pm 7.9%
Feeding	9.9 \pm 2.4%	13.6 \pm 2.4%	10.9 \pm 2.4%	26.0 \pm 8.5%	0.3 \pm 6.0%
Drinking	5.4 \pm 1.7%	7.6 \pm 1.7%	10.2 \pm 1.7%	24.0 \pm 10.7%	17.3 \pm 7.5%
Pre-laying	24.9 \pm 3.7% ^{a,†}	11.8 \pm 3.7% [‡]	8.0 \pm 3.7% ^b	n/a	n/a
Sitting	12.5 \pm 5.3%	8.6 \pm 5.3%	21.7 \pm 5.3%	1.8 \pm 0.7%	0.4 \pm 0.5%
Maintenance	6.2 \pm 1.2% [†]	3.4 \pm 1.2%	2.0 \pm 1.2% [‡]	0.0 \pm 1.9%	2.1 \pm 1.3%
Location					
Slat	44.5 \pm 3.4% ^{b,‡}	57.5 \pm 3.4% [†]	60.8 \pm 3.4% ^a	58.4 \pm 13.9%	43.8 \pm 9.9%
Scratching	32.1 \pm 3.2%	33.7 \pm 3.2%	33.3 \pm 3.2%	41.6 \pm 13.7%	55.6 \pm 9.7%
Nest boxes	23.4 \pm 3.7% ^a	8.5 \pm 3.7% ^b	5.9 \pm 3.7% ^b	0 \pm 0%	0 \pm 0%

¹Time spent in locomotion and redirected-oral behaviors were excluded due to low occurrence.

^{a-b}Different letters indicate significant mean differences within a row between females and males ($P < 0.05$).

^{†-‡}Different symbols refer to a tendency for mean difference within a row for male strains ($P < 0.05$).

$P = 0.06$) without differences in the relative liver weight among strains (Table 5; $F_{2,9} = 0.63$, $P = 0.56$). Livers scored as fatty livers showed no signs of hemorrhage(s). As indicated in Table 5, strain affected the weight of the fat pad ($F_{2,9} = 9.72$, $P = 0.006$), ovary ($F_{2,10} = 45.16$, $P < 0.001$), stroma ($F_{2,6.0} = 9.98$, $P = 0.012$), LYF ($F_{2,9} = 12.24$, $P < 0.001$), and tended to affect the number of LYF ($F_{2,6.1} = 3.57$, $P = 0.09$). Strain A hens had heavier stroma and LYF than B and C hens (Table 5), and the ovary of A hens had more LYF than those of B and C hens together ($F_{1,6.1} = 7.13$, $P = 0.037$). The presence of egg formation in progress ranged from 95% in A hens to 80% in C hens without significant differences ($F_{2,12.2} = 0.76$, $P = 0.49$).

After dissection, most hens showed keel bone fractures (A hens: 100%, B hens: 100%, and C hens: 85%) and more than half also showed keel bone deviations (A hens: 65%, B hens: 70%, and C hens: 65%). Most of the keel bone fractures were seen in the tip (i.e., caudal border) (95%), and strain B hens had a higher number of keel bone fractures (2.7 ± 0.4 fractures/hen) than C

hens (1.6 ± 0.4 fractures/hen; $t_7 = 3.21$, $P = 0.04$). Hen strains did not score differently for severity of keel bone deviations ($F_{2,9} = 0.04$, $P = 0.96$), and most of the observed keel bone deviations were mild (68%). Body weight was included as a covariate in the GLM model, and body weight was not a risk factor for high number of keel bone fractures in any of the 3 strains (strain A hens: $F_{1,15} = 1.16$, $P = 0.29$; strain B hens: $F_{1,15} = 0.35$, $P = 0.56$; and strain C hens: $F_{2,9} = 0.44$, $P = 0.52$).

DISCUSSION

There is a growing body of literature on the performance and welfare of slower growing broilers, while little research has been done on their parent stock. Here we describe and compare the performance and welfare of 3 combinations of slower and intermediate growing broiler breeders. According to breeding guidelines, slower and intermediate growing strains of broiler breeders were expected to show optimal performance and few signs of poor welfare and health with mild to moderate levels of feed restriction. Our results indicate that slower growing broiler breeder hens can achieve good reproductive performance (high and persistent laying rate at high hatchability and low mortality) with low feather coverage loss, low feeding motivation, and good foot health, relative to previous reports for conventional broiler breeders experiencing higher levels of feed restriction (Sandilands et al., 2005; van Emous et al., 2015c; Morrissey et al., 2014a,b; Arrazola et al., 2019a).

Performance of Slower Growing Broiler Breeders

Hens started laying earlier than expected according to breeding guidelines, and laying rate peaked at different ages among the hen strains. After the peak, laying rate persisted at a high rate for two of the hen strains (A and B) whereas laying rate dropped below 50% in 2 pens of strain C. In conventional broiler breeder hens, laying rate drops linearly after peak as body weight increases

Table 5. Anatomical traits of the reproductive system of slower growing broiler breeder hens at 53 wk of age (mean \pm SE).

Anatomical Measure	Strain of hens		
	A	B	C
Body weight (g)	3360.4 \pm 154.6 ^a	2257.3 \pm 48.5 ^b	2405.9 \pm 34.4 ^b
Relative liver ¹ (%)	2.13 \pm 0.13	2.20 \pm 0.13	2.00 \pm 0.13
Relative fat pad ¹ (%)	5.74 \pm 0.43 ^a	3.35 \pm 0.43 ^b	3.45 \pm 0.43 ^b
Ovary (g)	77.99 \pm 1.80 ^a	58.42 \pm 1.91 ^b	55.62 \pm 2.85 ^b
Oviduct (g)	60.44 \pm 2.05	65.05 \pm 2.05	64.16 \pm 2.05
Stroma (g)	7.24 \pm 0.34 ^a	5.27 \pm 0.34 ^b	5.51 \pm 0.43 ^b
LYF ² :			
Total weight (g)	64.79 \pm 2.56 ^a	49.18 \pm 2.56 ^b	48.81 \pm 2.86 ^b
Number	6.33 \pm 0.44	5.47 \pm 0.39	5.50 \pm 0.07
SYF ³ :			
Total weight (g)	2.23 \pm 0.40	1.38 \pm 0.40	1.46 \pm 0.41
Number	13.20 \pm 2.43	8.87 \pm 0.43	9.70 \pm 2.54
Broken follicles (no)	0.93 \pm 0.47	1.33 \pm 0.47	1.69 \pm 0.48
Atretic follicles (no)	0.07 \pm 0.20	0.33 \pm 0.20	0.07 \pm 0.20

Female strains: A hens (A), B hens (B), and C hens (C).

¹Relative to body weight

²Large yellow follicle (LYF): larger than 10 mm

³Small yellow follicle (SYF): between 10 and 5 mm

^{a-b}Different letters indicate significant mean differences within a row.

(e.g., Ross 308 [van Emous et al., 2015a; Arrazola et al., 2019b], Ross 708 [van der Klein et al., 2018], and Cobb 500 [Arabinar et al., 2020; Oviedo-Rodon et al., 2021]). Certainly, fast growth rate and excessive fat accumulation negatively impact the reproductive performance and health of broiler breeders, and the severity of obesity-related problems depends on individual and strain susceptibility to lipotoxicity (Heck et al., 2004; Chen et al., 2006; Renema et al., 2007; Walzem and Chen, 2014).

Broiler breeders in this study were feed restricted following strain-specific target growth rates and optimal body condition during rearing (see Arrazola and Torrey, 2021 for more details) and lay, but A and C hens were above target body weight after the peak in laying rate. In conventional broiler breeders, excessive accumulation of fat is a common factor associated with dysfunctional ovaries, hemorrhagic fatty liver syndrome (HFLS), and dysregulation of the hypothalamus-pituitary-gonads axis (HPG) resulting in reduced laying rate (Heck et al., 2004; Renema and Robinson, 2004; van der Klein et al., 2020). In our study, strain A (with an expected intermediate growth rate) had the fastest growth rate and heaviest body weight, heaviest fat pad, high prevalence of HFLS, and overdeveloped ovaries with a high number of LYF, suggesting multiple ovary hierarchies. Yet, these hens maintained a greater laying rate than indicated in the breeding guidelines for that strain and without signs of double ovulation (i.e., double-yolked eggs). These results suggest that strain A hens were less susceptible to the negative consequences of excessive fat accumulation (i.e., lipotoxicity) and needed lower feed restriction to sustain an optimal laying rate during mid lay compared to conventional broiler breeders. In comparison, hens from the slower growing strain C appeared to be more susceptible to lipotoxicity. Two out of 4 pens of strain C had a poor laying rate (around 40% during lay) and were heavier compared to the other two pens of strain C, both of which had optimal laying rate (above 70% during lay). When the feed restriction level was increased in the pens with heavier hens, the laying rate improved from 35% at 49 wk of age to 45% at 53 wk of age. Surprisingly, strains B and C did not differ in ovarian morphology or number/size of follicles, but both had lower values than A.

Overall, high and persistent laying rate led to high cumulative egg production in strain A and strain B by the end of the study (above 165 eggs/hen on average). Compared to previous research, the strains in our study had higher cumulative egg production than conventional broiler breeders (e.g., Ross 308: 143 eggs/hen [Arrazola et al., 2019b; Aviagen, 2021a], Ross 708: 137 eggs/hen [van der Klein et al., 2018, Aviagen, 2021b], and Cobb 500: 138 eggs/hen [Arabinar et al., 2020; Oviedo-Rodon et al., 2021]). Previous research with alternative strains also concluded that slower growing strains of broiler breeders can achieve higher egg production than conventional feed-restricted broiler breeders (Heck et al., 2004; Gebhardt-Henrich et al., 2018).

Research with conventional broiler breeders also described a decrease in hatchability when broiler

breeders approached 50 wk of age (van Emous et al., 2015b; Igbal et al., 2016; Gebhardt-Henrich et al., 2017; Arrazola et al., 2019b). This decline in hatchability is mainly driven by a decrease in fertility as roosters become heavier and less sexually active (Hocking and Bernard, 2000). Similar to what happens with hens, excessive body weight and fat content also result in negative consequences on the reproductive performance and health of broiler breeder roosters (Carter et al., 1972; Hocking and Bernard, 2000; Sarabia Fragoso et al., 2013). Throughout lay in the current study, fertility of hatching eggs was above 95% and rooster mortality was minimal (below 1%). All together, 2 of the 3 combinations of slower broiler breeder strains showed high reproductive performance (above the expected cumulative egg productive and high percentage of fertile eggs and hatched of fertile) and, due to their slower growth rate, slower growing strains of broiler breeders had low cumulative feed intake and low mortality (<2%) during lay.

Welfare of Slower Growing Broiler Breeder Hens

Conventional broiler breeders often show signs of poor welfare during lay such as poor feather coverage, presence of skin lesions, high feed intake motivation after feeding, poor foot health, and excessive mortality (Heck et al., 2004; Renema et al., 2007; Morrissey et al., 2014a; van Emous et al., 2015c). These problems relate to high body weight gain, compromised welfare during rearing, and forced mating and aggressive behavior from roosters (de Jong and van Emous, 2017). In this study, intermediate growing broiler breeder hens scored worse for foot lesions and feather coverage than slower growing broiler breeders (strain B and C). But despite differences among the three strains, slower and intermediate growing broiler breeder hens showed few signs of poor welfare, with little acute feather coverage loss, low prevalence and severity of foot lesions and hock burns, and low feeding motivation. Indeed, less than 15% of the hens were feeding 30 min after feed allocation and there was a bit of mash feed remaining in the feeders for most of the pens housing strains B and C hens (and some of the pens housing A hens). These results are in stark contrast to those with conventional broiler breeders during lay, where hens had higher feeding rate (Sandilands et al., 2005; van Emous et al., 2015c; Arrazola et al., 2019), cleaned-up their feeders in 2 to 3 h (Moradi et al., 2013; van Emous et al., 2015c), and showed behavioral signs of feeding frustration such as object pecking (Sandilands et al., 2005; Morrissey et al., 2014b; van Emous et al., 2015c).

Some, but not all, intermediate and slower growing broiler breeder hens still require acute/moderate feed restriction to control growth rate and allow them to achieve optimal reproductive performance (Jones et al., 2004; Heck et al., 2004). In this study, all three strains of broiler breeder hens were feed restricted during rearing

and lay. Interestingly, one of the slower growing broiler breeder strains assessed in Heck et al. (2004) was able to maintain a controlled body weight gain and high laying rate without feed restriction during rearing or lay. Chronic feed restriction is an ethical concern due to signs of distress and frustrated feeding behavior exhibited by most broiler breeders (Dawkins and Layton, 2012; Lindholm et al., 2018). The results from our study suggest that welfare problems in broiler breeders can be mitigated by selecting broiler breeder strains that are less susceptible to obesity-related problems (e.g., intermediate growing strains [A hens in this study]) or with a slow growth rate (e.g., slower growing strains [B hens in this study]), without a negative impact on reproductive performance.

Little research attention has focused on the prevalence of keel bone fractures and deviations in broiler breeder hens. Using keel bone palpation, previous research has reported that the prevalence and severity of keel bone damage was low in broiler breeder hens (Gebhardt-Henrich et al., 2017). Indeed, slower growing broiler breeder hens seemed to have higher and more severe keel bone damage than conventional broiler breeder hens, particularly in systems equipped with perches and platforms (Gebhardt-Henrich et al., 2018). The authors explained that these results may relate to higher laying rate and/or greater use of perches and platforms by slower growing broiler breeders than conventional broiler breeders. Compared to laying hens, greater breast musculature around the keel bone in broiler breeder hens can prevent keel bone damage during falls and collisions (Gebhardt-Henrich et al., 2017, 2018). For the same reason, assessing keel bone fractures and deviations using palpation can also underestimate keel bone damage in broiler breeders. Results from our study suggest that keel bone fractures were grossly underestimated via palpation as most of the hens (95%) had keel bone fractures upon dissection. Our results show that most hens had one or more keel bone fractures and a high percentage of hens also had keel bone deviations. Pens in our study were not equipped with elevated perches or platforms (although there was a step between the scratching area and the slats), and keel bone damage in broiler breeder hens could have occurred from forced and excessive mating activity by overweight roosters. Roosters are considerably heavier than hens, and this difference in body weight between hens and roosters was greater in slower growing hens compared to intermediate growing hens. In this study, the three hen strains scored similarly for keel bone deviation and fractures. However, compared to conventional broiler breeders, slower and intermediate growing broiler breeder hens may be at greater risk for keel bone damage due to the greater body weight difference between hens and roosters. Keel bone fractures are painful and threaten the well-being of injured birds (Riber et al., 2018) and more research is needed to understand the prevalence, severity, and causation of keel bone fractures and deviations in broiler breeders.

Welfare of Slower Growing Broiler Breeder Roosters

Information about the performance and welfare of broiler breeder roosters is limited. Roosters in this study were housed at the same hen-to-rooster ratio as commercial conditions and pens were not 'spiked' with the replacement of old/overweight roosters with young roosters around 40-45 weeks of age to avoid the expected drop in fertility during mid lay. Spiking broiler breeders imposes a risk for biosecurity, especially if the new roosters were raised off-site, and raises welfare concerns related to excessive aggressive behavior (e.g., injurious pecking and severe fighting) and high mortality during the first week after spiking (Arrazola et al., 2019b). Results in this study suggest that spiking was not needed with strain X or Y roosters; the roosters remained within the target body weight, had body weight uniformity, and low mortality until the end of the study. Additional studies are needed to see if slower and intermediate growing roosters still maintain high fertility and low mortality rates under commercial conditions.

Both strains of roosters showed signs of high feeding motivation; roosters finished their daily feed allotment in less than an hour. In addition, the intermediate growing roosters (strain X) needed a higher level of feed restriction to control for body weight gain than slower growing roosters (strain Y). In many selection programs, fast growing broiler breeder roosters are combined with slower growing broiler breeder hens to produce slower growing broilers. However, these roosters require chronic feed restriction during rearing and lay to maintain a steady growth rate to avoid the negative consequences on their health and reproductive performance.

CONCLUSIONS

Public pressure and consumer concerns about the welfare of conventional broilers are pushing the poultry industry towards using slower growing strains. Growing literature is focused on addressing this research topic for broilers (e.g., Torrey et al., 2021; Dawson et al., 2021; Dixon, 2020; Rayner et al., 2020; Weimer et al., 2020), but science-based recommendations for alternative strains of broiler breeders is lacking. Results from this research provide evidence that slower and intermediate growing broiler breeders can achieve good reproductive performance without compromising welfare and health outcomes. The level of feed restriction required to control for body weight gain resulted in fewer signs of feeding motivation than we have reported in studies with conventional strains. Our results also suggest that the susceptibility to obesity-related problems is strain specific. Further research is needed to understand how to optimize the performance and well-being of slower growing broiler and broiler breeders under commercial conditions through strain-specific management and nutritional requirements.

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DISCLOSURES

All the authors reviewed the manuscript and approved the submission to Poultry Science and confirmed that the manuscript has not been published or it is under consideration and review by another journal. AA was supported by a grant from Canadian Hatching Egg Producers and Mitacs Accelerate Postdoctoral Fellowship. This project was part of the larger Better Broiler Project, with support from Global Animal Partnership, Canada First Research Excellence Fund, anonymous breeding companies and the Ontario Agri-Innovation Alliance. We declare no conflict of interest on the publication of this manuscript.

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