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Research Article
Phenotypic Variations of Growth and Reproductive Performances Among Turkeys (*Meleagris gallopavo*)

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Abstract
This study was carried out with the aim of comparing the phenotypic variations of growth and reproductive performances among seven heritage varieties of turkeys with hybrid turkeys. Differences among turkey varieties for Body Weight (BW), Average Daily Gain (ADG) and Feed Conversion Ratio (FCR) were significant ($p \leq 0.05$) with Narragansett being the heaviest and Royal Palm showed the lowest BW and ADG. The mean ADG gradually increased up to 159 days of age and then decreased thereafter in heritage turkeys. Consistently better FCR for males and females reported in Blue Slate and White Holland, respectively. Narragansett was characterized by the highest semen volume and sperm count, while Bourbon Red had the lowest. White Holland had the highest sperm concentration and viability, while Bourbon Red had the lowest. Age at first egg (AFE) was also different among turkey varieties. Heritage turkeys are generally characterized by late sexual maturity. Among heritage varieties, Midget White reported the least AFE and highest egg productions than others. As expected, hybrid turkeys were superior to heritage birds in performance for most of the traits evaluated in the study. In conclusion, the differences observed in growth and reproductive performances within heritage turkeys could be useful for future breeding programs to improve the existing production and reproductive performances of turkeys.

Key words: Heritage turkeys, phenotypic variations, growth, reproductive performance

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The domesticated turkey, *Meleagris gallopavo*, which originated from North America, is raised throughout the world but its wild progenitor descends from Eastern and Southwestern United States and central/northern Mexico (Thornton *et al*., 2012). The present domesticated turkey has been developed by crossbreeding and line breeding programs and are characterized as a single breed with 8 distinct varieties based on the plumage color (Kennamer *et al*., 1992). The American Standard of Perfection (American Poultry Association, 2001) has recognized 8 distinct varieties of *M. gallopavo* as Black, Bronze, Narragansett, Slate, Beltsville Small White, Bourbon Red, Royal Palm and White Holland. The American Livestock Breeds Conservancy also recognizes other naturally mating domesticated turkey varieties such as Midget White and Jersey Buff that have not been accepted into the American Poultry Science standards including, American Poultry Association (Reese *et al*., 2010).

These varieties described by the American Standard of Perfection and American Livestock Breeds Conservancy, have been called heritage because of historic, range-based production system in which the birds are normally reared. To qualify as a heritage turkey, certain criteria including the capability to mate naturally, long productive lifespan and slow growth rate must be met (Reese *et al*., 2010). Commercial/hybrid turkeys developed for meat purpose, have a relatively higher rate of disease susceptibility, mainly because they have been highly selected for increased body weight and growth rate (Huff *et al*., 2005). The production per turkey bird has been doubled during last four decades mainly due to high selection pressure imposed for economically important traits; body weight, meat quality and egg production (Aslam *et al*., 2012). High disease susceptibility may be due to narrow genetic background (Kamara *et al*., 2007).

The different heritage turkey varieties have been identified based on plumage coloration as primary criterion (Kennamer *et al*., 1992). Though turkey varieties are considered a single breed, research evidence shows that significant differences exist among the populations of heritage and commercial turkey birds (Hartman *et al*., 2006). Several attempts have been made to examine the differences among turkey varieties at the phenotypic, molecular and biochemical levels. The recent study conducted by McCrea *et al*. (2012) compared the performances; weight gain, body weight, feed conversion, carcass weights and yield between commercial turkey and one of the heritage turkey (Bourbon Red) and observed significant difference between two varieties for live performances and carcass traits. Commercial turkey performed better than Bourbon Red for feed intake, weight gain, live weights, carcass weights and carcass yields. Gyenai (2005) reported that turkey varieties differed in the incidence and severity of susceptibility effects of toxic levels of furazolidone, which induces dilated cardiomyopathy. In addition, significant differences among heritage varieties have also been observed for plasma uric acid, a biomarker of oxidative stress (Hartman *et al*., 2006).

Differences among heritage varieties at the molecular level have also been investigated. Smith *et al*. (2005) distinguished the relatedness of five heritage turkey varieties using three molecular marker systems including randomly amplified polymorphic DNA (RAPD), microsatellite and SNPs and reported that Royal Palm is distinct from other varieties investigated. Kamara *et al*. (2007) compared the genetic relatedness of five turkey varieties using microsatellite markers and reported that Spanish Black was closely related to Bourbon Red, which is similar to the findings observed by Smith *et al*. (2005). The study did not support the claim made by Smith *et al*. (2005) that showed a closer relationship between Royal Palm and Narragansett. According to the mitochondrial DNA based analyses, Guan *et al*. (2015) reported closer genetic relationship among heritage turkey varieties than between heritage and wild turkeys. Thus, further improvement of domesticated turkeys to meet the human demand is dependent on within and between variations among turkeys. Such phenotypic variations among individuals or varieties of turkeys provide ample opportunities to select the best animals for breeding purposes. However, limited work pertaining to phenotypic differences among turkeys has been carried out. Thus, the primary objective of the present study was to compare the growth and reproductive performances among commercial and seven varieties of heritage turkeys.

MATERIALS AND METHODS

Turkey population and study duration: A total of 40 day-old poults from each heritage variety and 50 day-old poults from hybrid turkeys (CC) were obtained from two commercial breeders (Welp's Hatchery, Bancroft, IA and AG Forte LLC, Harrisonburg, VA, USA, respectively). The heritage birds comprised of seven different varieties including, Bourbon Red (BR), Blue Slate (BS), Narragansett (NA), Royal Palm (RP), Spanish Black (SB), White Holland (WH) and Midget White (MW). The study was carried out a total of 309 days during the period of May, 2011-March, 2012.

Management and phenotypes: Standard animal care procedures were carried out as described in the protocol approved by the Institutional Animal Care and Use Committee, Virginia Tech., USA (11-028-APSC). On receipt, the poults were weighed and wind-banded. The birds were raised at the Turkey Farm of the Department of Animal and Poultry Sciences, Virginia Tech, USA according to standard management protocol in floor pens for a period of 309 days. They were fed with a commercial diet (Big Spring Mill, Inc., Elliston, VA), which met the recommendations of National Research Council (NRC., 1994). Birds were randomly allocated to pens according to variety and sex. The normal commercial diets fed were Pre-starter (T-1) from 1-3 weeks of the age, Starter (T-2) from 3-6 weeks of the age, Grower (T-3) from 6-9 weeks of the age, Finisher (T-4) from 9-18 weeks of the age, Pre-breeder (TPB-1) from 18-24 weeks of the age and Breeder (TB-2) from 24 weeks of the age. Feed and water were provided *ad libitum*. Body Weight (BW) was measured in kilograms at 1, 34, 68, 159, 231 and 309 days of age. Feed intake was recorded for each variety starting from 34-231 days. Average Daily Gain (ADG) and Feed Conversion Ratio (FCR) were calculated using standard arithmetic.

Semen collection and evaluation: Semen was collected at three different times from each tom at weekly intervals starting from 35 weeks of age using the abdominal massage technique (Burrows and Quinn, 1937). The volume (V) of the semen was determined using a syringe. Sperm concentration (C) was estimated using a hemocytometer after dilution at a ratio of 1:500 (Bakst and Cecil, 1997). The total number of sperm/ejaculate (T) was calculated for each tom using the equation:

$$T = C \times V$$

Sperm viability was examined microscopically (400x) using eosin, nigrosin stains (Blom, 1950) and hancock stain and semen were gently mixed. The strain and semen smears were air dried and examined directly on a microscope. The proportions of live (eosin-impermeable) and dead (eosin-permeable) sperm cells in a sample were assessed on the basis of 100. The sperm cells that were white (unstained) were classified as live and those with pink or red coloration were classified as dead.

Measurement of reproductive parameters: Turkey hens were wing-tagged for easy identification during the period of laying. Trap nests were used from 20 weeks of age. Age at first egg (AFE), number of eggs and egg weight were recorded for each hen. Number of egg parameters was based on egg laid for a period of 10 weeks starting from 30 weeks of age. Eggs were weighed daily on the same day they were laid. Total egg production for each hen was estimated for two periods including 6 and 10 weeks. The individual egg production for 6 weeks was calculated excluding the first and last two weeks of 10 weeks of egg production. The average egg weight (g) was also calculated for 6 and 10 weeks separately for each hen. The egg weight was obtained using an electronic weighing balance with a sensitivity of 0.01 g.

Statistical analysis: Data were analyzed using PROC GLIMMIX of SAS 9.3 (SAS Inst. Inc., Cary, NC). The following statistical model was used for the analysis of phenotypic traits:

$$Y_{ijk} = \mu + L_i + S_j + (L \times S)_{ij} + e_{ijk}$$

where, Y_{ijk} is the parameter of interest that was measured and estimated for turkeys, μ is the overall population mean, L_i is the fixed effect of the turkey variety, S_j is the fixed effect of sex, $(L \times S)_{ij}$ is the interaction effect between the sex and variety and e_{ijk} is the residual error. Multiple comparisons were done using Tukey's test. Sex effect was omitted from the model for analyzing the reproductive parameters. The values were presented as least square Means±Standard Error. Results were considered significant at $p \leq 0.05$.

RESULTS AND DISCUSSION

Live body weight: Least square means of live Body Weight (BW) from day-one to 309 days of age for different varieties of turkeys is presented in Table 1. The interaction effect of sex "x" turkey variety on BW was significant ($p \leq 0.05$). The mean estimates for BW of turkey males at day-one, 34, 68, 159, 231 and 309 days of age ranged from 0.042±0.001 to 0.056±0.001, 0.612±0.03 to 1.350±0.03, 1.727±0.09 to 5.009±0.10, 5.192±0.29 to 22.017±0.28, 8.127±0.34 to 26.849±0.32 and 8.149±0.36 to 26.979±0.36 kg, respectively. The mean estimates for BW of turkey hens at day-one, 34, 68, 159, 231 and 309 days of age ranged from 0.039±0.001 to 0.055±0.001, 0.522±0.04 to 1.293±0.02, 1.386±0.10 to 4.094±0.07, 3.461±0.18 to 12.546±0.19, 4.321±0.23 to 14.086±0.24 and 4.507±0.23 to 14.843±0.19 kg, respectively.

As expected, CC turkeys had significantly higher average BW for males and females at all ages ($p \leq 0.05$). Within heritage turkeys, no significant difference among 34 and 68 days of age was observed in males and females ($p \geq 0.05$). The SB and BS

Table 1: Least square means of Body Weight (BW) in toms and hens of turkeys from day-old to 309 days of age

	BW (kg)							
Days	BR (13, 15)	BS (15, 21)	CC (12, 30)	MW (15, 15)	NA (16, 17)	RP (12, 25)	SB (16, 20)	WH (15, 21)
1	0.043±0.001^{b,c}	0.047±0.001^{b}	0.056±0.001^{a}	0.042±0.001^{c}	0.044± 0.001^{b,c}	0.046±0.001^{b,c}	0.048±0.001^{b}	0.044±0.001^{b,c}
	0.039±0.001^{d}	0.047±0.001^{b,c}	0.055±0.001^{a}	0.039±0.001^{d}	0.047± 0.001^{b}	0.044±0.001^{b,c}	0.045±0.001^{b,c}	0.043±0.011^{c,d}
34	0.703±0.04^{b}	0.619±0.03^{b}	1.350±0.03^{a}	0.663±0.03^{b}	0.725±0.03^{b}	0.612±0.03^{b}	0.707±0.03^{b}	0.663±0.03^{b}
	0.522±0.04^{b}	0.575±0.03^{b}	1.293±0.02^{a}	0.554±0.03^{b}	0.602±0.03^{b}	0.538±0.02^{b}	0.593±0.03^{b}	0.583±0.03^{b}
68	1.984±0.10^{b}	1.727±0.09^{b}	5.009±0.10^{a}	1.744±0.10^{b}	2.092±0.09^{b}	1.783±0.11^{b}	1.896±0.09^{b}	1.910±0.09^{b}
	1.539±0.12^{b}	1.567±0.08^{b}	4.094±0.07^{a}	1.386±0.10^{b}	1.608±0.08^{b}	1.422±0.07^{b}	1.526±0.08^{b}	1.489±0.08^{b}
159	6.447±0.29^{b,c}	6.153±0.25^{b,c}	22.017±0.28^{a}	5.776±0.27^{c}	7.294±0.25^{b}	5.192±0.29^{c}	6.112±0.24^{b,c}	6.602±0.25^{b,c}
	3.987±0.32^{b,c}	3.895±0.22^{b,c}	12.546±0.19^{a}	3.794±0.28^{b,c}	4.111±0.24^{b}	3.461±0.18^{c}	3.797±0.22^{b,c}	4.197±0.22^{b}
231	10.124±0.34^{b}	9.496±0.30^{b,c}	26.849±0.32^{a}	8.272±0.32^{c}	10.150±0.29^{b}	8.127±0.34^{c}	9.140±0.28^{b,c}	9.216±0.30^{b,c}
	4.865±0.37^{b,c}	4.658±0.26^{b,c}	14.086±0.24^{a}	4.523±0.33^{b,c}	5.379±0.27^{b}	4.321±0.23^{c}	5.047±0.26^{b}	5.039±0.26^{b,c}
309	10.357±0.33^{b}	9.765±0.29^{b,c}	26.979±0.36^{a}	8.853±0.32^{c,d}	10.743±0.28^{b}	8.149±0.36^{d}	9.781±0.28^{b,c}	9.567±0.29^{b,c,d}
	5.202±0.37^{b}	4.739±0.25^{b}	14.843±0.19^{a}	4.733±0.32^{b,c}	5.381±0.27^{b}	4.507±0.23^{c}	5.281±0.25^{b}	5.354±0.26^{b}

^{a,b,c,d}Means within rows with different superscripts are significantly different ($p \leq 0.05$), BW (kg) was measured at 1, 34, 68, 159, 231 and 309 days of age, For each body measurement, first and second rows represent tom and hen BW, respectively, Values are expressed as LS means of BW±SE, Seven different varieties of heritage turkeys including Bourbon Red (BR), Blue Slate (BS), Narragansett (NA), Royal Palm (RP), Spanish Black (SB), White Holland (WH) and Midget White (MW) and Commercial strain (CC) turkeys were used for the present study, The number of toms and hens used for the study from each variety is given within the parenthesis, respectively

males had significantly higher BW ($p \leq 0.05$) at day-one compared to MW turkeys. The NA males had significantly higher BW ($p \leq 0.05$) at 159, 231 and 309 days of age compared to MW and RP turkeys. In addition, NA and BS turkey hens had significantly higher BW ($p \leq 0.05$) at day-one compared to BR, MW and WH turkeys. The WH hens at 159 days and NA hens at 231 and 309 days of age had significantly higher BW ($p \leq 0.05$) compared to RP turkeys (Table 1).

In this study, the comparison of males and females CC turkeys with their counterparts of heritage varieties showed that CC turkeys had significantly higher BW than that of heritage turkeys at all ages. The CC turkeys have been developed by crossing a sire line and a dam line. Sire lines are normally selected for better growth related traits, while dam lines are selected for both growth and reproductive traits (Huff *et al*., 2005; Kamara *et al*., 2007). The BW changes for heritage varieties have a similar pattern compared to CC turkeys. Among heritage turkeys, NA males and females were heaviest, while RP birds were lightest. Heritage turkeys have been characterized as slow growth (Reese *et al*., 2010). Several studies have reported the changes of BW with age in different lines of turkeys. Havenstein *et al*. (2007) compared the change of BW of 1966 vs. 2003 type turkeys at different ages starting from day-old to 196 days of age. Body weights in CC turkeys of the current study were similar to 2003 type turkeys. But, BW of heritage turkeys was lower than these of 1966 vs 2003 type turkeys. Laudadio *et al*. (2009) also reported that BW of Nicholas Large White female turkeys at different ages starting at 30 up to 114 days of age. The BW reported was similar to CC turkeys of our study but as expected higher than of the heritage turkeys. Ilori *et al*. (2010) also compared the growth performances of pure and crossbred turkeys at different ages up to 140 days of age. The average BW of exotic turkeys on 1, 7, 28, 56, 84, 112 and 140 days of age were higher than that of the crossbred. The values reported by Ilori *et al*. (2010) were lower than that of CC turkeys in this study and those were closer to these of the heritage varieties. McCrea *et al*. (2012) compared the body weight at 4, 7, 10, 13 and 17 weeks of ages between commercial and one of the heritage turkeys (Bourbon red) and reported commercial turkey had higher BW than the BR turkeys for each of the age periods evaluated. These observations were similar to the study and commercial turkeys performed better than BR turkeys. The study conducted by Ramkrishna *et al*. (2012) evaluated the BW variation of three different genotypes at hatch, 4, 8, 12, 14 and 16 weeks of ages and also reported commercial genotypes performed better than others. However, the values observed were smaller than our study. Further, Gibril *et al*. (2013) studied the BW of one of the commercial turkey (BUT Big 6) at 9 and 16 weeks of age reported lighter values compared to this study which may be due to genotype variation.

In the present study, BW up to 309 days of age was measured, while in earlier investigations, it was measured, up to 140 days of age. The BWs both in male and female CC turkeys were approximately three times more than that of heritage birds at 159, 231 and 309 days of age. At 34, 68, 159, 231 and 309 of ages, NA males and females were heaviest, while RP birds were lightest among heritage birds. Differences in BW may be due to different varieties of turkeys used for the studies. The BW is dependent on the varieties of turkeys suggesting that genotype accounts for the BW differences.

Average Daily Gain (ADG): Least square means of ADG of turkey varieties is presented in Table 2. The ADG was

Table 2: Least square means of Average Daily Gain (ADG) of toms and hens of turkeys by different periods of the age

	ADG (kg)							
Age periods	BR (13, 15)	BS (15, 21)	CC (12, 30)	MW (15, 15)	NA (16, 17)	RP (12, 25)	SB (16, 20)	WH (15, 21)
1-34	0.020±0.001^{b}	0.017±0.001^{b}	0.039±0.001^{a}	0.019±0.001^{b}	0.021±0.001^{b}	0.017±0.001^{b}	0.020±0.001^{b}	0.018±0.001^{b}
	0.014±0.001^{b}	0.016±0.001^{b}	0.037±0.001^{a}	0.016±0.001^{b}	0.017±0.001^{b}	0.015±0.001^{b}	0.016±0.001^{b}	0.016±0.001^{b}
35-68	0.038±0.002^{b}	0.033±0.002^{b}	0.108±0.002^{a}	0.032±0.002^{b}	0.040±0.002^{b}	0.034±0.002^{b}	0.035±0.002^{b}	0.037±0.002^{b}
	0.030±0.003^{b}	0.029±0.001^{b}	0.082±0.001^{a}	0.024±0.002^{b}	0.029±0.002^{b}	0.026±0.002^{b}	0.027±0.002^{b}	0.027±0.001^{b}
69-159	0.049±0.003^{b,c}	0.049±0.002^{b,c}	0.187±0.003^{a}	0.044±0.003^{b,c}	0.057±0.003^{b}	0.037±0.003^{c}	0.046±0.003^{b,c}	0.051±0.002^{b,c}
	0.027±0.003^{b,c}	0.025±0.002^{b,c}	0.093±0.003^{a}	0.025±0.003^{b,c}	0.027±0.003^{b,c}	0.022±0.002^{c}	0.025±0.002^{b,c}	0.029±0.002^{b}
160-231	0.051±0.003^{a,b}	0.046±0.003^{b}	0.066±0.003^{a}	0.035±0.003^{b}	0.039±0.003^{b}	0.041± 0.003^{b}	0.042±0.003^{b}	0.036±0.003^{b}
	0.012±0.004^{a,b}	0.010±0.003^{b}	0.021±0.002^{a}	0.010±0.002^{a,b}	0.018±0.003^{a,b}	0.012±0.002^{a,b}	0.017±0.003^{a,b}	0.012±0.003^{b}
232-309	0.003±0.003^{a}	0.003±0.003^{a}	0.006±0.004^{a}	0.007±0.004^{a}	0.008±0.003^{a}	0.004± 0.003^{a}	0.008±0.003^{a}	0.004±0.003^{a}
	0.004±0.004^{a}	0.001±0.002^{a}	0.010±0.002^{a}	0.002±0.003^{a}	0.001±0.003^{a}	0.002±0.003^{a}	0.003±0.002^{a}	0.004±0.003^{a}
1-309	0.034±0.001^{b}	0.031±0.001^{b,c}	0.087± 0.001^{a}	0.029±0.001^{c,d}	0.035±0.001^{b}	0.026±0.001^{d}	0.032±0.001^{b,c}	0.031±0.001^{c,b,d}
	0.017±0.001^{b}	0.015±0.001^{b,c}	0.048±0.001^{a}	0.015±0.001^{b,c}	0.017±0.001^{b}	0.014±0.001^{c}	0.017±0.001^{b}	0.017±0.001^{b,c}

^{a,b,c,d}Means within rows with different superscripts are significantly different ($p \leq 0.05$). The ADG was estimated at different periods of the age. 1- 34 days-ADG between 1 and 34, 35- 68 days, ADG between 35 and 68, 69-159 days-ADG between 69 and 159, 160-231 days, ADG between 160 and 231, 232-309 days, ADG between 232, 309 and 1-309 days, ADG between 1 and 309 days. First and second rows represent the tom and hen ADG, respectively. Values are expressed as LS means of ADG±SE. Seven different varieties of heritage turkeys including Bourbon Red (BR), Blue Slate (BS), Narragansett (NA), Royal Palm (RP), Spanish Black (SB), White Holland (WH) and Midget White (MW) and Commercial strain (CC) turkeys were used for the present study. The number of toms and hens used for the study from each variety is given within the parenthesis, respectively

estimated for the five different periods at which BW measurements were made between day-one and 309 days of age. The sex "x" variety interaction for ADG was also significant ($p \leq 0.05$) at the different ages except from 232-309 days. Differences among varieties for ADG at different periods were significant ($p \leq 0.05$) except between 232 and 309 days of age. The mean estimates for ADG of turkey toms for different periods of age ranged from 0.017±0.001 to 0.039±0.001, 0.032±0.002 to 0.108±0.002, 0.037±0.003 to 0.187±0.003, 0.035±0.003 to 0.066±0.003, 0.003±0.004 to 0.008±0.003 and 0.026±0.001 to 0.087±0.001 kg, respectively. Within heritage turkey varieties, NA turkey had significantly higher ADG ($p \leq 0.05$) at age periods including 69-159 days and 1-309 days compared to RP turkey (Table 2). The mean estimates for ADG of turkey hens for different periods of age ranged from 0.014±0.001 to 0.37±0.001, 0.024±0.002 to 0.082±0.001, 0.022±0.002 to 0.093±0.003, 0.010±0.002 to 0.021±0.002, 0.001±0.002 to 0.010±0.002 and 0.014±0.001 to 0.048±0.001 kg, respectively. The CC turkey toms and hens had significantly higher ADG ($p \leq 0.05$) at each period of age except 232-309 days period compared to heritage turkeys. Within heritage turkey varieties, WH turkey hens had significantly higher ADG ($p \leq 0.05$) at 69-159 days age period compared to RP turkeys. In addition, NA, BR, MW, SB and WH turkey hens had significantly higher ADG ($p \leq 0.05$) at 1-309 days age period compared to RP turkey (Table 2).

As expected, the mean ADG increased up to 159 days of age and then decreased thereafter in all the different varieties. CC turkeys differed in the pattern of ADG and had significantly higher ADG, when compared to heritage turkeys. The heritage turkeys showed similar pattern of ADG throughout the study. Both toms and hens reached a maximum ADG between 69-159 days of age. After 159 days, the mean ADG decreased gradually among the turkeys. When considered the ADG of the whole study period, the mean ADG of toms in all varieties was double than that of hens. In addition, the mean ADG in CC toms and hens was approximately three times more than that of heritage turkeys. Case *et al.* (2012) reported that ADG of breeder turkey sire was 0.230 kg from 105-133 days of age. The ADG of Nicholas Large White females was estimated as 0.077 kg between 31 and 114 days of age (Laudadio *et al.*, 2009). Torres-Rodriguez *et al.* (2007) used CC turkey hens to estimate the ADG up to 92 days of age and reported that ADG of those hens was 0.075 kg. Brenoe and Kolstad (2000) compared the ADG between BUT-9 and Nicholas turkeys and reported that males showed a higher ADG compared with females. Nicholas showed the lower ADG compared with BUT-9. Both turkeys had a maximum ADG (0.130 kg for BUT-9 and 0.120 kg for Nicholas) at 56-77 days of age followed by a slight decrease thereafter. The ADG for CC turkeys studied here were higher than those from previously reported studies except that of Case *et al.* (2012) study, where they used breeder turkey sires. McCrea *et al.* (2012) compared the ADG at 4, 7, 10, 13 and 17 weeks of ages between commercial and one of the heritage turkeys (Bourbon Red Red) and reported ADG of commercial turkey was higher and increased gradually than BR turkeys. Gibril *et al.* (2013) reported lighter ADG as 66.25 g day^{-1} for commercial turkey (BUT Big 6) between 9 and 16 weeks. of age. The ADG in heritage turkeys was lower than these described in published reports. This is a good indication for heritage turkeys being characterized for slow growth. Overall, NA turkeys had higher ADG among heritage birds while RP turkeys had the least.

Table 3: Least square means of average Feed Conversion Ratio (FCR) of tom and hens of turkeys by different periods of the age

	FCR							
Age periods	BR (13, 15)	BS (15, 21)	CC (12, 30)	MW (15, 15)	NA (16, 17)	RP (12, 25)	SB (16, 20)	WH (15, 21)
34-68	2.37±0.30^{b}	3.21±0.26^{b}	1.38±0.28^{a}	3.15±0.28^{b}	2.97±0.25^{b}	2.27±0.30^{b}	2.44±0.25^{b}	2.45±0.26^{b}
	3.11±0.33^{a}	3.25±0.22^{a}	1.99±0.20^{c}	3.91±0.28^{a}	2.90±0.24^{b}	2.93±0.19^{b}	3.27±0.22^{a}	3.34±0.22^{a}
69-159	5.02±0.26^{a}	3.96±0.23^{b,c}	2.86±0.21^{d}	3.68±0.24^{b,c}	3.94±0.22^{b,c}	5.45±0.25^{a}	4.70±0.21^{a,b}	3.38±0.22^{c,d}
	6.15±0.28^{a}	4.93±0.19^{b}	4.08±0.17^{c}	4.93±0.24^{b}	5.36±0.20^{a,b}	5.08±0.16^{b}	4.79±0.19^{b}	4.44±0.19^{b}
160-231	7.29±1.25^{c}	8.03±1.11^{b,c}	12.88±1.19^{a}	8.91±1.17^{b,c}	10.14±1.07^{b}	7.67±1.25^{b,c}	9.19±1.04^{b,c}	9.84±1.09^{b,c}
	14.08±1.39^{a,b}	15.86±0.94^{a,b}	15.37±0.86^{a,b}	18.73±1.20^{a}	12.88±1.02^{b}	15.12±0.86^{a,b}	12.88±0.95^{b}	14.32±0.95^{a,b}
34-231	6.12±0.40^{a}	5.89±0.35^{a,b}	5.19±0.38^{b}	6.13±0.37^{a}	6.10±0.34^{a}	6.67±0.40^{a}	6.72±0.33^{a}	5.92±0.35^{a,b}
	9.54±0.44^{a,b}	8.71±0.30^{b}	6.97±0.28^{c}	10.62±0.38^{a}	8.13±0.32^{b}	9.27±0.27^{a,b}	8.25±0.30^{b}	7.76±0.30^{b}

^{a,b,c,d}Means within rows with different superscripts are significantly different ($p \leq 0.05$). The FCR was calculated at different periods of the age. 34-68 days, FCR between 34 and 68, 69-159 days, FCR between 69 and 159, 160-231days, FCR between 160, 231 and 34-231 days, FCR between 34 and 231 days, First and second rows represent tom and hens ADG, respectively. Values are expressed as LS means of FCR±SE. Seven different varieties of heritage turkeys including Bourbon Red (BR), Blue Slate (BS), Narragansett (NA), Royal Palm (RP), Spanish Black (SB), White Holland (WH) and Midget White (MW) and Commercial strain (CC) turkeys were used for the present study. The number of toms and hens used for the study from each variety is given within the parenthesis, respectively

Feed Conversion Ratio (FCR): Least square means of FCR for different varieties of turkeys is presented in Table 3. The FCR was estimated for four different periods of their age including 34-68, 69-159, 160-231 and 34-231 days. The sex "x" variety interaction on FCR was significant ($p \leq 0.05$) at each age. Differences among varieties for FCR at different periods of age were also significant ($p \leq 0.05$). The mean FCR of turkey toms for four different periods of age ranged from 1.38±0.28 to 3.21±0.26, 2.86±0.21 to 5.45±0.25, 7.29±1.25 to 12.88±1.19 and 5.19±0.38 to 6.72±0.33, respectively. Within heritage turkey toms, BS, MW, NA, SB and WH turkeys had significantly lower FCR ($p \leq 0.05$) at the age of 69-159 days compared to BR and RP turkeys (Table 3). The BR had significantly lower FCR compared to NA turkeys at 160-231 days of age. The mean FCR of turkey hens for different periods of age ranged from 1.99±0.20 to 3.91±0.28, 4.08±0.17 to 6.15±0.28, 12.88±1.02 to 18.73±1.20 and 6.97±0.28 to 10.62±0.38, respectively. Within heritage turkeys, NA and RP hens had significantly lower FCR ($p \leq 0.05$) at the age of 34-68 days compared to other heritage turkeys. At the age of 69-159 days, BS, MW, RP, SB and WH hens had significantly lower FCR ($p \leq 0.05$) compared to BR turkeys. The MW turkeys reported the significantly higher ($p \leq 0.05$) FCR compared to other heritage turkeys at the age of 34-231 days. The CC turkeys had significantly lower FCR for toms and hens. In heritage birds, BS and WH turkeys had lowest FCR for toms and hens, respectively.

Feed efficiency is often assessed as either FCR or Residual Feed Intake (RFI). In this study, FCR was used, which indicates each variety's ability to convert feed to body weight as a measure of feed efficiency. In general, toms showed the better FCR compared to hens. The FCR for toms and hens of all turkey varieties increased gradually with age. The FCR for heritage varieties was higher than those reported in the CC turkeys except during the period between 160 and 231 days. The WH and BS turkeys had the better FCR among the heritage varieties for the period of age between 34 and 231 days. Gibril *et al.* (2013), reported FCR was 2.82 for commercial turkey (BUT Big 6) between 9 and 16 weeks. of age. According to Case *et al.* (2012), the FCR estimated for the breeder turkey sires was 2.96 between 105 and 133 days of age. McCrea *et al.* (2012) compared the FCR at 4, 7, 10, 13 and 17 weeks of ages between commercial and one of the heritage turkeys (Bourbon Red Red) and reported superior FCR in commercial turkey than BR. In another study, FCR estimated for Nicholas Large White females was 2.98 for the period between 31 and 114 days of age and also reported that the FCR gradually increased with the age (Laudadio *et al.*, 2009). According to Havenstein *et al.* (2007), the FCR increased with age, which is consistent with present work. Heritage turkeys are characterized as slow growth. It is therefore not surprising that FCR of heritage turkeys is higher than that for CC birds. However, WH and BS turkeys among the heritage turkeys have shown fairly a better FCR. The direct measures of FCR can be used to study the performance traits that affect the overall efficiency. Therefore, FCR information can be incorporated in breeding programs as one of the efficiency related parameters. In general, low FCR reduces the cost of production for feeds and improves the profit margin of the turkey industry.

Semen quality characteristics: The comparison of mean values of ejaculate volume, sperm concentration, total number of sperm per ejaculate and sperm viability among different varieties of turkeys is presented in Table 4. The ejaculate volume, total number of sperm per ejaculate and sperm viability were significant ($p \leq 0.05$) among varieties. The mean ejaculate volume ranged from 0.049±0.02 to 0.179±0.01 mL across different varieties of turkeys. The largest ejaculate

Table 4: Comparison of semen quality parameters in heritage and commercial turkey toms

	Semen quality parameters			
Turkey varieties	Ejaculate volume (mL)	Sperm concentration ($\times 10^9$ mL^{-1})	Total number of sperm ($\times 10^8$ ejaculate^{-1})	Sperm viability (%)
BR (13)	0.049±0.02^{c}	1.754±0.24^{a}	0.970±0.55^{c}	82.408±1.21^{a,b}
BS (15)	0.102±0.01^{b,c}	2.488±0.19^{a}	2.514±0.44^{b}	79.689±0.96^{b}
CC (12)	0.136±0.01^{a,b}	2.212±0.25^{a}	3.200±0.58^{a,b}	86.315±1.27^{a}
MW (15)	0.133±0.01^{a,b}	2.532±0.22^{a}	3.285±0.52^{a,b}	83.724±1.13^{a,b}
NA (16)	0.179±0.01^{a}	2.231±0.19^{a}	4.124±0.43^{a}	84.070±0.94^{a,b}
RP (12)	0.099±0.01^{b,c}	2.151±0.51^{a}	2.066±0.49^{b}	83.548±1.06^{a,b}
SB (16)	0.102±0.01^{b,c}	2.028±0.17^{a}	2.165±0.44^{b}	83.085± 0.96^{a,b}
WH (15)	0.096±0.01^{b,c}	2.598±0.19^{a}	2.641±0.43^{b}	84.521±0.95^{a}

^{a,b,c}Means within columns with different superscripts are significantly different ($p \leq 0.05$). Seven different varieties of heritage turkeys including Bourbon Red (BR), Blue Slate (BS), Narragansett (NA), Royal Palm (RP), Spanish Black (SB), White Holland (WH) and Midget White (MW) and Commercial (CC) turkeys were used for the present study. The number of toms used for the study from each variety is given within the parenthesis. Values are expressed as LS Means±SE

volume was collected from NA birds, while BR birds produced smallest average volume. The mean sperm concentration, was not significant ($p \geq 0.05$), ranged from 1.754±0.24 and 2.598±0.19 ($\times 10^9$ mL^{-1}). The WH turkeys had the highest sperm concentration, while BR birds had the lowest. The mean total number of sperm per ejaculate ranged from 0.970±0.55 to 4.124±0.43 ($\times 10^8$ ejaculate^{-1}). The NA turkeys had significantly higher number of sperm per ejaculate, while BR had the lowest. The mean sperm viability ranged from 79.689±0.96 to 86.315±1.27% for different turkey varieties. The CC turkeys had significantly higher sperm viability while BS turkeys had the lowest ($p \leq 0.05$).

In the present study, NA turkeys were characterized by the largest average semen volume and highest total number of sperm. The BR turkeys had the smallest volume of semen, lowest sperm concentration and lowest total number of sperm. The WH turkeys had the highest sperm concentration. When compared the sperm viability, CC turkeys were characterized by the highest sperm viability while BS turkeys had the lowest. In general, these results indicated that heritage turkey had better semen quality parameters compared to CC turkeys. The differences in semen quality parameters in relation to turkey varieties indicated in the present study were also reported by Kotlowska *et al.* (2005). The data that have been published recently provide the following information for average semen volume, average sperm concentration and total sperm count per ejaculate. Kotlowska *et al.* (2005) reported the sperm characteristics of three strains of turkey including Big-6 (0.53 mL, 6.90×10^9 mL^{-1}, 3.64×10^9), Hybrid Large White (0.44 mL, 6.3×10^9 mL^{-1}, 2.83×10^9) and Nicholas (0.36 mL, 7.02×10^9 mL^{-1}, 2.59×10^9). In addition, several studies reported the semen volume and concentration of Big-6 strain: 0.37 mL and 5.94×10^9 mL^{-1} (Kozlowski *et al.*, 2004), 0.35 mL and 6.54×10^9 mL^{-1} (Jankowski *et al.*, 2002). The semen volume and sperm concentration depend on the strains, age and frequency of semen collection (Bakst and Cecil, 1992; Noirault and Brillard, 1999; Kotlowska *et al.*, 2005; Slowinska *et al.*, 2011). The ejaculate volume, sperm concentration and total number of sperm of the present study were lower than that of previously published data (Noirault and Brillard, 1999; Kotlowska *et al.*, 2005; Slowinska *et al.*, 2011). This may be due to strain differences used for different studies. By analyzing present data, it was obvious that semen volume was affected by the variety of turkeys, which is consistent with previously published data (Kotlowska *et al.*, 2005). However, we did not see any significant difference for sperm concentration among the turkey varieties in the present study. Semen viability was also consistent with data published by Noirault and Brillard (1999). Ngu *et al.* (2014) compared the semen characteristics of two breeds of turkey and reported genotype had the effect for semen volume, total sperm per ejaculation and daily sperm output. Overall, exotic breed performed better than local and the values reported were lower than this study, which may be due to genotypic variation among turkeys.

Egg production performance of heritage and CC turkeys: The comparison of mean AFE, egg production for 6 and 10 weeks, average egg weight for 6 and 10 weeks among different turkey varieties is presented in Table 5. The AFE, egg production and average egg weight for 6 and 10 weeks were significant ($p \leq 0.05$) among varieties. The mean AFE ranged from 184.62±8.59 to 258.10±7.91 days across the different turkey varieties. The CC turkeys had significantly lower AFE ($p \leq 0.05$). In heritage birds, MW had the lowest AFE (228.20±9.93 days). The mean egg production for the periods of 6 and 10 weeks among turkey varieties was significant ($p \leq 0.05$). The mean egg production for the periods of 6 and 10 weeks ranged from 1.96±3.79 to 24.36±3.28 and 6.85±5.49 to 33.95±4.76, respectively. In the both periods, BR turkeys had significantly lower egg production ($p \leq 0.05$),

Table 5: Comparison of reproductive parameters in heritage and commercial turkey hens

		Reproductive parameters			
		Cumulative egg production[3] (eggs hen^{-1})		Average egg weight[4] (g)	
		6	10	6	10
Turkey varieties[1]	AFE[2] (Days)	(Weeks)		(Weeks)	
BR (15)	246.35±12.38^{a}	1.960±3.79^{c}	6.85±5.49^{b}	74.30±1.42^{b,c}	75.21±1.15^{b,c}
BS (21)	238.20±12.44^{a}	7.190±2.46^{b,c}	10.28±3.57^{b}	74.29±1.13^{b,c}	74.72±1.07^{b,c}
CC (30)	184.62±8.59^{b}	12.99±2.39^{b,c}	20.64±3.46^{a}	90.73±0.84^{a}	91.31±0.80^{a}
MW (15)	228.20±9.93^{a}	24.36±3.28^{a}	33.95±4.76^{a}	73.39±0.96^{c}	74.21±0.92^{c}
NA (17)	232.37±7.90^{a}	17.53±2.62^{a,b}	25.74±3.81^{a}	77.65±0.77^{b}	77.75±0.74^{b}
RP (25)	249.00±7.71^{a}	9.230±2.21^{b,c}	14.64±3.22^{b}	77.45±0.74^{b}	78.12±0.71^{b}
SB (20)	233.45±8.40^{a}	10.31±2.47^{b,c}	15.20±3.59^{b}	75.42±0.89^{b,c}	75.16±0.80^{b,c}
WH (21)	258.10±7.91^{a}	6.190±2.54^{c}	12.36±3.69^{b}	77.37±0.90^{b}	77.63±0.76^{b}

^{a,b,c}Means within columns with different superscripts are significantly different ($p \leq 0.05$). [1]Seven different varieties of heritage turkeys including Bourbon Red (BR), Blue Slate (BS), Narragansett (NA), Royal Palm (RP), Spanish Black (SB), White Holland (WH) and Midget White (MW) and Commercial (CC) turkeys were used for the present study. The number of females from each variety is given within the parenthesis. [2]Age at first egg (AFE) was recorded for each hen in days. Values are expressed as LS means of AFE±SE. [3]Egg production was individually recorded for a period of 10 weeks starting from 30-40 weeks of age. The cumulative egg production for each hen was estimated for a period of 6 and 10 weeks. The individual egg production of 6 weeks was calculated by excluding the first and last two weeks egg production from the period of 10 weeks egg production. Values are expressed as LS means of egg number for 6 and 10 weeks±SE. [4]Egg weight was individually measured and recorded. The average egg weight (g) was calculated for the period of 6 and 10 weeks separately for each hen

while MW turkeys had significantly higher egg production. The mean average egg weight for both periods of 6 and 10 weeks among turkey varieties was significant ($p \leq 0.05$). The mean average egg weight for the periods of 6 and 10 weeks ranged from 73.39±0.96 to 90.73±0.84 g and 74.21±0.92 to 91.31±0.80 g, respectively where, CC turkeys had significantly higher average egg weight ($p \leq 0.05$) while MW turkeys had the lowest for both periods.

One of the major problems encountered by turkey industry today is low production of eggs. Therefore, increased selection pressure for egg numbers, modifications in management and lighting programs have been using as a solution to improve the low egg production. Photo-stimulation is generally used for CC turkey industry to increase the egg production. In the lighting program, turkey hens are exposed to a low lighting schedule (8 h light: 16 h dark) at the beginning and then photo-stimulated (>14 h light) between 29 and 31 weeks of age. However, photo-stimulation at young ages will have negative effects of delayed sexual maturity, low egg production, low fertility and low hatchability. The non-commercial turkey strains achieve optimal reproductive body weight at approximately 30 weeks of age (Applegate and Lilburn, 1998). But, if photo-stimulation is carried out at correct stage, present day commercial turkey can reach their reproductive body weight well before 30 weeks of age. Turkey hens reached sexual maturity and laid eggs as early as 21-22 weeks of age with the proper photo-stimulation for egg production (Siopes, 2010). According to present study, mean AFE for CC turkeys was reported as 184.62 days, which was higher than that of the published reports. The mean AFE of heritage varieties ranged between 228.20-258.10 days, which was also higher than that of published data. It appeared that AFE depends on the variety of turkeys. Heritage turkey hens are generally characterized by late sexual maturity. Egg production was individually recorded for a period of 10 weeks starting from 30-40 weeks of age. The cumulative egg production for each hen was estimated for a period of 6 and 10 weeks. The cumulative egg production for the period of 6 weeks for a hen was calculated excluding first and last two weeks egg production from the period of 10 weeks of egg production. Egg production gradually increased over the 10 weeks production period. When compared the egg production among different varieties of turkeys, MW turkeys showed the much better egg laying performances compared to BR turkeys. There is a negative correlation between egg production and body weight, which is mediated mainly as a decrease in egg production (Nestor *et al*., 2000). The CC turkeys have been selected for increased growth and body weight. We did not observe high egg production from CC hens though they reached sexual maturity earlier. The average egg weight increased from 6-10 weeks except RP and SB turkeys. The CC turkeys had significantly higher average egg weight compared to heritage turkeys. The average egg weight among heritage varieties did not significantly differ ($p \geq 0.05$) between the production periods of 6 weeks and 10 weeks. Nestor *et al*. (2000) compared the egg production performance of two turkey lines, which included the Random Bred Control (RBC) line and subline of RBC (F) line selected for increased body weight. The mature body weight of the RBC was 21 lb compared to 38 lb for the F line. The 180 day egg production for the RBC line was 92.6 eggs hen^{-1} compared to 68.7 eggs hen^{-1} for F line.

Egg weight increased from 89-98 g for the RBC vs the F line. This suggests that when turkeys are selected for increased growth and body weight, the body weight is negatively associated with egg production but positively associated with egg weight. Anandh *et al*. (2012) studied the effect of rearing systems on reproductive performances of turkey and reported higher egg weight from intensive rearing system but values were smaller than our study.

CONCLUSION

In conclusion, the phenotypic variations among different varieties of turkeys used in the present study accounts for observed differences in the growth, production and reproductive parameters suggesting that these differences serve as base information for the poultry breeders as well as academia and could be useful for future breeding programs to improve the existing productive and reproductive performances of heritage turkeys.

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