Performance and processing yield comparisons of Large White male turkeys by genetic lines, sources, and seasonal rearing

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ABSTRACT Large White male turkey genetic lines (**GL**) comparison in performance and processing yields under the same conditions are rare in the literature. Two rearing experiments (**EXP**) were conducted to accomplish 2 objectives. The first objective was to test the effects of poult source and genetic lines on performance and processing yields. The second objective was to extract season and growth patterns when comparing both EXP common treatments. In EXP 1, male poults from 5 different sources were randomly assigned to 48 concrete: litter-covered floor pens. In EXP 2, male poults from 7 different genetic lines were randomly assigned to 48 concrete: litter-covered floor pens. For both EXP, the experimental design was a completely randomized block design with a one-factor arrangement. Both EXP were placed in the same house with the same management and nutrition in two separate seasons of the same year. Bird performance and carcass processing yield were analyzed in SAS 9.4 or JMP 15.1 in a mixed model. In EXP 1 no significant difference in BW or processing yield was observed. However, a similar GL from a commercial hatchery had an improved feed conversion ratio (**FCR**) over the same GL sourced directly from the genetic company hatchery. In EXP 2, statistical differences were observed in performance and breast meat yield depending on the GL. A season effect was observed when comparing the two EXP. Birds raised in the fall season had a 2 kg BW increase, on average, over their spring counterparts. This difference in BW can also be observed in a statistically higher breast meat yield by the birds raised in the fall over the ones raised in the spring. In conclusion, a comparison between GL resulted in effects due to genetic line, poult source, and rearing season on bird performance and carcass yield.

Key words: Genetic lines, processing, performance, growth rate, seasonal rearing

INTRODUCTION

A significant part of the poultry industry's commercial success has been the proprietary genetic information of competing breeder companies (Tixier-Boichard et al., 2009). The proprietary information keeps the industry competitive and updated to challenges and production problems, in higher turnover than another animal husbandry, and keeps the poultry industry as a low-cost animal protein source. However, unshared proprietary information may create a lack of public (open source) knowledge of the genetic lines and their characteristics. Tixier-Boichard et al. (2009) stated that keeping up with the characterization by monitoring poultry's genetic pool is critical to providing information to the market.

Previously, researchers comparing carcass characteristics in turkeys have utilized pure lines and crosses (Nestor et al., 2001). Pure lines (great grandparents and grandparents) produce parent stock breeders and, ultimately, commercial meat birds. Breeder companies select pure lines; they have the pedigree until the parents are sold to commercial integrators that sell meat. Thus, poultry integrators have parent stock and produce offspring which are the final generation of birds used for animal protein. However, there is a need to update and compare commercial lines and not pure lines.

A rapid growth genetic selection strategy that increases body weight and breast meat yields have also brought challenges such as leg problems, livability, ascites, muscle abnormalities, pale soft exudative meat, and even cooked product characteristics (Anthony, 1998). In some cases, unexpected consequences such as animal welfare issues and increases in rare recessive alleles with adverse effects on fitness (Hocking, 2014) have been observed. In turkeys, increased body weight selection resulted in a lower immune response in 2 commercial breeds (Bayyari et al., 1997).

It is known that BW and breast meat yield increases in cooler temperature rearing relative to warmer temperature rearing (Case et al., 2010). In uncontrolled

environment production houses, the temperature fluctuates depending on the season. Spring rearing (January to May) can produce heat stress at the end of the production cycle when birds are at their heaviest body weight. Birds reared in the fall season (July−December) have the advantage of heat during the brooding period and lower temperatures when the birds are the heaviest at market age. Heat stress can produce oxidative stress (Akbarian et al., 2016), reduce voluntary feed intake, and reduce BWG (Sahin et al., 2001). By having different genetic traits, different strains could behave differently to heat stress. Therefore, two experiments were conducted to rear, monitor, and analyze different strains of turkeys reared during the spring and fall seasons.

The study herein was conducted to compare the performance and processing yield of different genetic lines of Large White turkeys in 2 experiments conducted in the same research house and under the same nutritional regime in different production seasons, fall and spring.

MATERIALS AND METHODS
Treatments and Experimental Design

For the first experiment (**EXP**), a completely randomized block design with a one-factor arrangement (poult source) was used. The poult source will be the main factor in this experiment, where the genetic lines and hatcheries where it came from will be considered as part of it. A total of 5 sets of poults with 3 genetic lines were compared. The first 3 sets were sourced from the primary breeder hatchery and the other 2 from commercial hatcheries. The labels used for the treatments (sets of poults) were assigned as L1, L2, L3, L1H, and L2H. The poults that share the same genetic information but come from the commercial hatcheries were labeled with an "H." The L1 and L2 had 9 replicates, while the other treatments had ten replicates. Each treatment was represented in each of the 4 blocks at least once.

For EXP 2, a completely randomized block design with a one-factor arrangement of treatments was used. A comparison of 7 genetic lines as treatments was made. The genetic lines were represented as L1H2, L2, L4, L5, L6, L7, and L8. The L1 and L2 treatments were the same genetic lines as L1 and L2 in EXP 1 and came from the same hatchery. The L2 genetic line in EXP 2 came from the same hatchery as in EXP 1. However, the L1 treatment does not share the same commercial hatchery as its counterpart in EXP 1, thus it will be labeled L1H2. Treatments from L4 to L8 were sourced from the same genetic company hatchery. The L1H2, L2, and L6 had nine replicates each, while the L4 had seven, the L5 and L8 five, and the L7 had four replicates each.

Comparison between experiments was done with the L1 and L2 genetic lines. These lines were labeled as L1 EXP 1, L1 EXP 2, L2 EXP 1, and L2 EXP 2, and data was analyzed as one factorial arrangement with 4 levels. Other genetic lines were not added to the analysis because they were not replicated in both experiments.

The difference in replicates in both EXP was due to the lower availability of the birds in those lines. Each treatment was represented in each of the 4 blocks at least once.

Housing and Management

Both EXP were conducted in the same double curtain-sided turkey house with clay floors. There were a total of 48 pens (8.4 m^2/pen). All pens were bedded with fresh pine shavings. In EXP 1, birds were reared from January to May. For EXP 2, birds were reared from July to December during the same year as EXP 1. There were 22 birds per pen. The birds were weighed individually at 4 wk and then every 3 wk until 19 wk of age. The weight of each pen of birds plus culls and mortalities was used to determine the feed conversion ratio (**FCR**). Feed and water were offered ad libitum throughout both EXP. All animal handling procedures were approved by the North Carolina State University Institutional Animal Care and Use Committee.

Feeding Program

Six feed phases were fed to the birds (starter 1, starter 2, grower 1, grower 2, finisher 1, and finisher 2) on a feed weight per bird feeding program (Table 1). Within each EXP, all birds were fed the same feed and the same amount of each phase on a per bird basis adjusted for each mortality within each pen. Feed weight was recorded and was added to a known weight feeder. At 4, 7, 10, 13, 16, and 19 wk feeders combined with unconsumed feed were weighed to determine feed disappearance as intake (**FI**), which was used to calculate FCR.

Feed Analysis

Proximate analysis was outsourced for dry matter, crude protein, crude fat, and minerals for samples (250 g) of each diet by phase (Carolina Analytical Services, Bear Creek, NC).

Processing

At 19 wk, one-half of the birds were processed at a commercial turkey processing plant. A live BW of the experimental units was recorded at the rearing facility on the day of transport to be used for processing yield values. Cold carcass weight was recorded at the processing plant. The cold carcasses were then cut and weighed into the total breast, major and minor breast, wings, legs, thighs, back, frame, and skin. The percentage of the cold carcass was based on live BW. The percentage of total and cut yield was based on a cold carcass. Statistical analysis was conducted using SAS 9.4 using a proc

Table 1. Turkey dietary ingredient composition.

Ingredients (%)	Starter 1	Starter 2	Grower 1	Grower 2	Finisher 1	Finisher 2
Corn	18.60	22.00	26.20	34.30	40.70	44.50
Wheat	20.00	20.00	20.00	20.00	20.00	20.00
Soybean meal	38.00	35.00	30.00	22.50	17.00	13.40
Poultry meal	10.00	10.00	10.00	10.00	10.00	10.00
Calcium carbonate	1.80	1.65	1.58	1.45	1.10	1.08
Monocalcium phosphate	2.55	2.35	2.25	2.00	1.50	1.35
Methionine[1]	0.45	0.43	0.38	0.30	0.28	0.25
Lysine[2]	0.45	0.44	0.41	0.33	0.33	0.30
Threonine	0.15	0.13	0.13	0.08	0.08	0.08
Salt	0.20	0.20	0.20	0.20	0.20	0.20
Mineral premix[3]	0.20	0.20	0.20	0.20	0.20	0.20
Choline chloride	0.20	0.20	0.20	0.20	0.20	0.20
Vitamin mix[4]	0.20	0.20	0.20	0.20	0.20	0.20
Selenium mix	0.05	0.05	0.05	0.05	0.05	0.05
Sodium bicarbonate	0.13	0.13	0.13	0.13	0.13	0.13
Poultry fat	7.03	7.03	8.09	8.08	8.05	8.08
Ingredient Total:	100.00	100.00	100.00	100.00	100.00	100.00
Kg of feed per birds[5]	2.27	4.55	7.27	10.00	13.64	15.91

[1]Feed grade, DL-Methionine (99%), donated by Evonik North America.

[2]Feed grade L-Lysine monohydrochloride (98.5%). donated by Ajinomoto North America.

[3]The mineral premix provided the following per kg of diet: manganese, 120 mg; zinc, 120 mg; iron, 80 mg; copper, 10 mg; iodine, 2.5 mg.

[4]Donated by DSM Nutritional Products; vitamin premix provided the following per kg of diet: vitamin A, 26,455 IU; vitamin D3, 7,936 IU; vitamin E, 132 IU; vitamin B12, 0.08 mg; biotin, 0.51 mg; menadione, 8 mg; thiamine, 8 mg; riboflavin, 26.67 mg; pantothenic acid, 44 mg; vitamin B6, 16 mg; niacin, 220 mg; folic acid, 4 mg.

[5]Kilograms of feed per bird in each feed phase, the feed was changed to the next phase after birds ate the previous feed phase amount of feed.

mixed model. The subsamples' mean was used as the experimental unit (pen), and the block was the random effect.

Statistical Analysis

Both experiments (EXP 1 and EXP 2) had a completely randomized block design. Data for both EXP were analyzed using the PROC MIXED procedure from SAS 9.4. or JMP 15.1 (SAS Institute, Cary, NC). Both software packages were used to complement their strengths, SAS 9.4 for its tables and JMP 15.1 to organize, curate, and graph data. Significant differences in main effects were separated using the Tukey HSD test with a $P \leq$ of 0.05. The processing data contained several unbalanced subsamples per experimental unit (pen). Thus, all the subsamples were nested and not averaged. For the comparison of between lines in different experiments, the statistical analysis was done as a one-factor ANOVA with four levels (L1 EXP 1, L1 EXP 2, L2EXP 1, and L2 EXP 2) and 4 random blocks.

RESULTS

Feed Analysis

Calculated nutrient content for North Carolina State University manufactured feed is presented in Table 2. The nutrient analysis of all 4 feeds is presented in Table 3 and reflects the calculated nutrient content.

Performance Parameters

In EXP 1, differences due to poult source were observed for bird body weight (**BW**) at placement and until 16 wk (Table 4). At 19 wk, there was no statistical difference on bird BW due to poult source. A higher and lower BW gain (**BWG**) was observed depending on the treatment and age. No consistent pattern was observed

Table 2. Calculated nutrient contents (%) for both turkey experiments by feed phase.

Nutrient	Starter 1	Starter 2	Grower 1	Grower 2	Finisher 1	Finisher 2
Crude protein	30.70	29.50	27.20	23.90	21.60	20.00
ME (kcal/Kg)	3,086	3,126	3,232	3,318	3,400	3,439
Crude fat	9.80	9.80	10.90	11.00	11.10	11.20
Lysine	1.89	1.80	1.65	1.39	1.25	1.14
Methionine[1]	0.84	0.81	0.73	0.62	0.58	0.53
Methionine + Cysteine[1]	1.23	1.18	1.08	0.93	0.87	0.80
Tryptophan[1]	0.33	0.31	0.28	0.24	0.21	0.19
Threonine[1]	1.19	1.12	1.04	0.87	0.79	0.73
Arginine[1]	1.89	1.80	1.64	1.42	1.25	1.15
Valine[1]	1.31	1.25	1.15	1.01	0.91	0.84
Calcium	1.50	1.41	1.35	1.25	1.03	0.99
Available phosphorus	0.75	0.71	0.68	0.63	0.52	0.49
Sodium	0.19	0.19	0.18	0.18	0.18	0.18
Chloride	0.18	0.18	0.18	0.18	0.18	0.19

[1]Calculated as digestible amino acids.

Table 3. Nutrient analyses of diets fed to turkeys.[1]

Nutrient (%)	Experiment 1					
	Starter 1	Starter2	Grower 1	Grower 2	Finisher 1	Finisher 2
Moisture	11.40	11.60	11.20	10.83	11.21	10.96
Fat	9.15	8.75	12.03	11.01	10.96	11.63
Protein	29.72	29.60	28.63	24.55	23.45	18.23
Ash	8.34	7.31	7.55	6.38	6.27	5.12
Phosphorus[2]	0.91	0.81	0.83	0.80	0.89	0.72
Calcium	1.42	1.38	1.44	1.35	1.26	1.00
Sodium	0.16	0.14	0.16	0.15	0.16	0.16

Nutrient (%)	Experiment 2					
	Starter 1	Starter2	Grower 1	Grower 2	Finisher 1	Finisher 2
Moisture	11.13	11.10	11.00	10.52	10.63	10.56
Fat	8.31	8.39	9.58	10.70	9.61	11.20
Protein	30.29	30.99	27.55	24.96	23.11	20.70
Ash	7.50	7.45	7.20	6.70	5.67	4.82
Phosphorus[2]	1.00	0.97	1.00	0.97	0.80	0.75
Calcium	1.45	1.57	1.40	1.42	1.02	0.95
Sodium	0.15	0.13	0.13	0.14	0.16	0.18

[1]Feed analysis was performed by Carolina Analytical Services (17570 NC Highway 902, Bear Creek, NC 27207).
[2]Total phosphorus in diet treatments.

Table 4. Poult source and genetic line[1] effect on male turkey body weight in kg/bird.

Poult source	Age (wk)						
	0	4	7	10	13	16	19
				(Experiment 1)			
L1	0.065[a]	1.54[a]	4.20[a]	7.83[a]	11.98[a]	16.59[ab]	19.45
L2	0.058[c]	1.24[b]	3.56[c]	6.93[b]	11.20[b]	15.76[b]	19.075
L3	0.057[c]	1.32[b]	3.68[bc]	7.31[ab]	11.56[ab]	15.98[ab]	19.54
L1H[2]	0.055[d]	1.41[ab]	4.02[ab]	7.72[a]	11.97[a]	16.89[a]	19.92
L2H[3]	0.060[b]	1.33[b]	3.79[b]	7.31[ab]	11.44[ab]	16.23[ab]	19.81
SEM[4]	0.004	0.06	0.13	0.19	0.24	0.32	0.30
P-value	<0.0001	0.003	0.0006	0.0014	0.03	0.015	0.30

Genetic line	Age (wk)						
	0	4	7	10	13	16	19
				(Experiment 2)			
L1H2	0.056[b]	1.11	3.49[ab]	7.06[abc]	11.52[ab]	16.42[a]	21.26[ab]
L2	0.060[a]	1.14	3.49[a]	7.14[a]	11.69[a]	16.74[a]	21.85[a]
L4	0.046[c]	1.10	3.33[abc]	6.82[abcd]	11.33[abc]	16.28[ab]	21.40[ab]
L5	0.046[cd]	1.04	3.13[c]	6.60[d]	10.93[c]	15.60[c]	20.49[c]
L6	0.046[cd]	1.09	3.28[bc]	6.69[bcd]	11.13[bc]	15.74[bc]	20.78[bc]
L7	0.045[cd]	1.09	3.25[abc]	6.70[bcd]	11.22[abc]	16.21[abc]	21.18[abc]
L8	0.045[d]	1.11	3.42[ab]	7.08[abc]	11.55[ab]	16.35[ab]	21.48[ab]
SEM[5]	0.004	0.03	0.08	0.12	0.16	0.20	0.27
P-value	<0.0001	0.12	0.0002	<0.0001	0.0003	<0.0001	<0.0001

Genetic line	Age (wk)						
	0	4	7	10	13	16	19
				(Experiment 1&2 comparison)			
L1 Exp 1	0.055[d]	1.36[a]	4.02[a]	7.70[a]	11.93	16.88	19.86[b]
L1 Exp 2	0.056[c]	1.11[b]	3.49[b]	7.05[b]	11.52	16.41	21.28[a]
L2 Exp 1	0.065[b]	1.53[a]	4.19[a]	7.81[a]	11.96	16.56	19.45[b]
L2 Exp 2	0.060[a]	1.14[b]	3.49[b]	7.14[b]	11.69	16.73	21.85[a]
SEM[6]	0.002	0.06	0.11	0.143	0.16	0.21	0.21
P-value	<0.0001	<0.0001	<0.0001	0.002	0.10	0.27	<0.0001

[a,b,c,d]Means within a column lacking a common superscript differ ($P \leq 0.05$).
[1]Genetic lines (L) with different numbers have different genetic characteristics and traits.
[2]Poults from genetic line one sourced from commercial hatcheries.
[3]Poults from genetic line two sourced from commercial hatcheries.
[4]Maximum observed standard error of the mean for a min of n = 9 replicates and up to n = 10, 6 degrees of freedom.
[5]Maximum observed standard error of the mean for a min of n = 4 replicates and up to n = 10, 4 degrees of freedom.
[6]Maximum observed standard error of the mean for a min of n = 9 replicates for all treatments, 3 degrees of freedom.

Table 5. Poult source and genetic line[1] effect on male turkey body weight gain (kg/bird).

	Age (wk)					
Poult source	0−4	4−7	7−10	10−13	13−16	16−19
	————————————— (Experiment 1) —————————————					
L1	1.48a	2.66a	3.63b	4.14b	4.60b	2.89b
L2	1.18b	2.32b	3.37c	4.26b	4.57b	3.31ab
L3	1.26b	2.36b	3.63b	4.26b	4.43b	3.55a
L1H[2]	1.35ab	2.69a	3.94a	4.60a	5.32a	3.50a
L2H[3]	1.27b	2.46ab	3.52bc	4.26b	4.79b	3.57a
SEM[4]	0.06	0.08	0.07	0.10	0.12	0.18
P-value	0.003	0.0004	<0.0001	0.004	<0.0001	0.01

	Age (wk)					
Genetic line	0−4	4−7	7−10	10−13	13−16	16−19
	————————————— (Experiment 2) —————————————					
L1H2	1.08	2.38a	3.56ab	4.47	4.90ab	4.84
L2	1.11	2.36ab	3.64a	4.57	5.06a	5.11
L4	1.07	2.24abc	3.49ab	4.51	4.95ab	5.12
L5	1.02	2.09c	3.47ab	4.33	4.66bc	4.91
L6	1.07	2.19bc	3.41b	4.45	4.60c	5.04
L7	1.06	2.17abc	3.45ab	4.53	4.99ab	4.97
L8	1.09	2.32ab	3.65a	4.47	4.79abc	5.14
SEM[5]	0.03	0.07	0.09	0.07	0.10	0.13
P-value	0.23	0.0001	0.043	0.25	0.0002	0.17

	Age (wk)					
Genetic line	0−4	4−7	7−10	10−13	13−16	16−19
	————————————— (Experiment 1&2 comparison) —————————————					
L1 Exp 1	1.36a	2.69a	3.94a	4.60a	5.31a	3.49b
L1 Exp 2	1.11b	2.38b	3.57b	4.47a	4.90b	4.86a
L2 Exp 1	1.53a	2.65a	3.63b	4.14b	4.60c	2.89c
L2 Exp 2	1.14b	2.35b	3.66b	4.55a	5.05ab	5.12a
SEM[6]	0.06	0.07	0.05	0.05	0.08	0.15
P-value	<0.0001	0.0002	0.0002	<0.0001	<0.0001	<0.0001

[a,b,c]Means within a column lacking a common superscript differ ($P \leq 0.05$).
[1]Genetic lines (L) with different numbers have different genetic characteristics and traits.
[2]Poults from genetic line one sourced from a commercial hatchery.
[3]Poults from genetic line two sourced from a commercial hatchery.
[4]Maximum observed standard error of the mean for a min of n = 9 replicates and up to n = 10, 6 degrees of freedom.
[5]Maximum observed standard error of the mean for a min of n = 4 replicates and up to n = 10, 4 degrees of freedom.
[6]Maximum observed standard error of the mean for a min of n = 9 replicates for all treatments, 3 degrees of freedom.

(Table 5). The L1 treatment had the higher BWG at 4 wk, but the lowest at 19 wk. No statistical difference was observed in FI due to treatments at 19 wk (Table 6). Birds sourced from the L1H set had an improved FCR at 19 wk when compared to the L1 and L2 counterparts (Table 8).

In EXP 2, differences due to genetic lines were observed for bird BW at placement, 7, 10, 13, 16, and 19 wk (Table 4). The L2 line where the heaviest birds with no shared population mean. However, by market age (19 wk) the L1H2, L4, L7, and L8 genetic lines were similar to L2 and similar to lower BW genetic lines. Birds of all the treatments had a higher and lower BWG through 4 to 16 wk (Table 5). At 19 wk, the BWG comparison of the treatments was not significant. The FI of L5 and L6 genetic lines of birds were lower when compared to the birds of L2, L4, and L8 but were not statistically different from L1and L7 at 19 wk (Table 6). No significant differences were found in FCR at 19 wk due to genetic lines (Table 8).

When comparing the genetic lines present in both EXP 1 and EXP 2, one can observe a statistical difference in the first weeks of age, where the birds in EXP 1 were heavier than birds in EXP 2. However, at the end of the trials, the birds of EXP 2 were heavier. The BWG and FI of the birds follow a similar trend as BW (Tables 5−7). The lowest FCR was achieved by the L1 genetic line but not different than the L2 in EXP 2 (Table 8).

Processing

For EXP 1, no statistical differences were observed between poult sources in processing data (Tables 8 and 9). For EXP 2, statistical differences were found in the processed birds' live BW (Table 9). The L2 birds were the heaviest, and consequently, all cut-up parts, but the frame was heavier as well (Table 9). When examining the parts yield based on the cold carcass weight, the only differences found were in the major and total breast weight (Table 9). Birds from the genetic line L4 had the highest major and total breast yield, while L1H2 and L6

Table 6. Poult source and genetic line[1] effect on male turkey feed intake (kg/bird).

	Age (wk)					
Poult source	0−4	0−7	0−10	0−13	0−16	0−19
			(Experiment 1)			
L1	2.07	6.19[a]	13.09	22.27	34.22	43.75
L2	1.81	5.55[b]	12.06	21.28	33.34	43.16
L3	1.92	5.52[b]	12.19	21.28	33.57	43.7
L1H[2]	1.91	5.99[ab]	12.52	22.7	35.67	44.58
L2H[3]	1.91	5.74[ab]	12.44	21.61	34.19	44.53
SEM[4]	0.08	0.21	0.39	0.48	0.64	0.7
P-value	0.12	0.02	0.15	0.05	0.07	0.5

	Age (wk)					
Genetic line	0−4	0−7	0−10	0−13	0−16	0−19
			(Experiment 2)			
L1H2	1.55	5.18	11.38[abc]	20.94[a]	33.22[ab]	45.71[ab]
L2	1.63	5.29	11.67[a]	21.07[a]	33.23[ab]	46.20[a]
L4	1.59	5.23	11.56[ab]	20.96[a]	33.11[abc]	46.19[a]
L5	1.54	4.98	11.07[bc]	19.97[b]	31.69[bc]	44.12[b]
L6	1.58	5.09	11.036[c]	20.24[a]	31.78[c]	44.15[b]
L7	1.55	5.02	11.12[bc]	20.41[a]	32.76[abc]	45.87[ab]
L8	1.58	5.14	11.42[abc]	21.09[a]	33.59[a]	46.67[a]
SEM[5]	0.04	0.01	0.04	0.34	0.46	0.59
P-value	0.28	0.19	0.23	0.01	0.01	0.0003

	Age (wk)					
Genetic line	0−4	0−7	0−10	0−13	0−16	0−19
			(Experiment 1&2 comparison)			
L1 Exp 1	1.80[ab]	5.88[a]	12.38[ab]	22.43[a]	35.38[a]	44.30[bc]
L1 Exp 2	1.55[b]	5.16[b]	11.37[c]	20.94[b]	33.23[b]	45.73[ab]
L2 Exp 1	2.06[a]	6.17[a]	13.05[ab]	22.22[a]	34.18[ab]	43.71[c]
L2 Exp 2	1.63[b]	5.28[b]	11.67[bc]	21.07[b]	33.27[b]	46.26[a]
SEM[6]	0.06	0.15	0.26	0.32	0.35	0.49
P-value	<0.0001	<0.0001	<0.0001	0.0009	0.0012	0.0022

[a,b,c]Means within a column lacking a common superscript differ ($P \leq 0.05$).

[1]Genetic lines (L) with different numbers have different genetic characteristics and traits.

[2]Poults from genetic line one sourced from a commercial hatchery.

[3]Poults from genetic line two sourced from a commercial hatchery.

[4]Maximum observed standard error of the mean for a min of n = 9 replicates and up to n = 10, 6 degrees of freedom.

[5]Maximum observed standard error of the mean for a min of n = 4 replicates and up to n = 10, 4 degrees of freedom.

[6]Maximum observed standard error of the mean for a min of n=9 replicates for all treatments, 3 degrees of freedom.

had the lowest yield. Genetic lines L2, L5, L7, and L8, were statistically similar to L4 (Table 9).

A difference in both yields in kg and percentage was found in the major and total breast values when comparing processing yields of the common genetic lines in both experiments (Tables 9 and 10), where the birds from genetic line L2 performed above the genetic line L1 independent of the experiment.

Environmental Temperature

The mean maximum, minimum, average, and dew points for the Raleigh Durham area environmental conditions are presented in Table 11. This data was collected from the Raleigh-Durham international airport station collected by the National Weather Service and accessed from The Weather Company website (2021).

DISCUSSION

The poults' hatchery source was as important as to genetic advancements. Based on EXP 1 performance results, the hatchery sourcing was critical for the L1

genetic line but not for the L2 genetic line. The L1 sourced from the commercial hatchery (L1H) had a higher BWG at 19 wk and improved FCR than the same genetic line sourced from the primary breeder (L1). The L2 and L2H were not statistically different in performance. Caution must be implemented with this comparison since only two commercial hatcheries were used, each with different breeder's ages. It is recognized that the breeder's ages for this experiment are not known. These are critical to record for future experiments because it is possible that poults' age can affect poult quality, but is not obvious that will affect BW at market age. In turkey hens in the age group of 39 to 48 wk were classified as the best are egg fertilization rate, hatching rate of fertilized eggs, and highest scoring for poult quality (Mróz and Orlowska, 2009). In turkeys hen age poult physical defects (eye, umbilical, and leg abnormalities, poor motor activity, and unabsorbed yolk sac) are affected by hen age (Mróz et al., 2019). Older hens lay heavier eggs than younger hens, this produces heavier poults at hatch (Applegate and Lilburn, 1999; Schaefer et al., 2006). However, it has been stated older hens do not affect the growth of the poult or intestinal growth (Applegate et al., 1999). This idea is also

Table 7. Poult source and genetic line[1] effect on male turkey period feed intake (kg/bird).

	Age (wk)					
Poult source	0–4	4–7	7–10	10–13	13–16	16–19
	———————————— (Experiment 1) ————————————					
L1	2.07	4.12[a]	6.89	9.17	11.98	9.47[bc]
L2	1.81	3.74[ab]	6.51	9.21	12.06	9.82[abc]
L3	1.92	3.60[b]	6.67	9.10	12.28	10.17[ab]
L1H[2]	1.91	3.80[ab]	6.89	9.14	12.61	9.33[c]
L2H[3]	1.91	3.84[ab]	6.69	9.19	12.58	10.38[a]
SEM[4]	0.08	0.15	0.19	0.20	0.31	0.17
P-value	0.12	0.05	0.35	0.99	0.40	0.001

	Age (wk)					
Genetic line	0–4	4–7	7–10	10–13	13–16	16–19
	———————————— (Experiment 2) ————————————					
L1H2	1.55	3.63	6.20[ab]	9.56[a]	12.28[ab]	12.52
L2	1.63	3.66	6.38[a]	9.40[ab]	12.26[ab]	12.91
L4	1.59	3.64	6.28[ab]	9.44[ab]	12.13[ab]	13.15
L5	1.54	3.43	6.10[ab]	8.90[b]	11.73[ab]	12.33
L6	1.58	3.50	5.95[b]	9.19[ab]	11.50[b]	12.39
L7	1.55	3.47	6.10[ab]	9.29[ab]	12.35[ab]	13.11
L8	1.58	3.56	6.27[ab]	9.67[a]	12.52[a]	12.98
SEM[5]	0.04	0.09	0.14	0.18	0.28	0.31
P-value	0.28	0.21	0.03	0.01	0.01	0.11

	Age (wk)					
Genetic line	0–4	4–7	7–10	10–13	13–16	16–19
	———————————— (Experiment 1&2 comparison) ————————————					
L1 Exp 1	1.80[ab]	3.81[ab]	6.90[a]	9.13	12.57	9.37[b]
L1 Exp 2	1.55[b]	3.62[b]	6.20[b]	9.55	12.27	12.49[a]
L2 Exp 1	2.06[a]	4.11[a]	6.88[a]	9.17	12.04	9.53[b]
L2 Exp 2	1.63[b]	3.65[b]	6.39[b]	9.43	12.27	12.87[a]
SEM[6]	0.06	0.12	0.14	0.16	0.21	0.17
P-value	<0.0001	0.008	0.0003	0.22	0.42	<0.0001

[a,b,c]Means within a column lacking a common superscript differ ($P \leq 0.05$).

[1]Genetic lines (L) with different numbers have different genetic characteristics and traits.

[2]Poults from genetic line one sourced from a commercial hatchery.

[3]Poults from genetic line two sourced from a commercial hatchery.

[4]Maximum observed standard error of the mean for a min of n = 9 replicates and up to n = 10, 6 degrees of freedom.

[5]Maximum observed standard error of the mean for a min of n = 4 replicates and up to n = 10, 4 degrees of freedom.

[6]Maximum observed standard error of the mean for a min of n = 9 replicates for all treatments, 3 degrees of freedom.

supported by Schaefer et al. (2006) that found no statistical difference in poult BW after 63 d post-hatch in BW between 55- and 33-wk-old hens.

In broilers, Vieira and Moran (1999) stated that the hen age is irrelevant to live broiler performance when eggs are the same weight. Broiler BW at 6 wk was similar for breeder flock age; however, FCR was higher for the older flock (Joseph and Moran, 2005). The authors found that the hatch window was earlier for 41 wk flocks vs. 32 wk old flocks (Joseph and Moran, 2005). Chickens sourced from mid-age hens had a higher innate immune system when compared to the ones sourced from early or late hens (Saunders-Blades and Korver, 2015). Breeders, egg collection, incubation and embryo temperature, moisture at transfer, hatch window, and transportation are all aspects of measuring the poult source quality (Lopez and Hergott, 2014). All these aspects should be studied in each specific operation to account for a "hatchery effect" that should be studied in the future.

The results herein provide information on the different ways birds grow over time, depending on the source and season. Growth curves have been developed to compare species (Anthony et al., 1991; Knížetová et al., 1995), where it was concluded that selection age for BW

compared to their mature weight is critical. In turkey production, the Von Bertalanffy model was used to high coefficient of determination (R^2) and Mean Square Error (MSE) when developing growth curves in different breeding systems (Sogut et al., 2016). These grow curves are essential to determine feed requirements and live weight (ŞENGÜL and Kiraz, 2005). However, these models need to be updated, compared to genetic lines, and be applied to heat stress situations. New approaches are being used to predict growth such as the statistical analysis of turkeys' grunt sounds to predict growth (Abdel-Kafy et al., 2020). These types of data sets can be valuable in the future to build prediction models or growth curves.

Rapid growth at the beginning of production was observed in the statistically higher performance and BW of L1 in the first stages of life. In the first experiment, L1 had a higher BW, BWG in the first weeks of age. By the end of the experiment, all treatments could catch up to a point where there were no significant differences at 19 wk in BW. A plateau in the growth curve of L1 was reached, but not to the other treatments. In the second experiment, differences in BWG and FCR were observed until 16 wk, with no significant differences at 19 wk. In

Table 8. Poult source and genetic line[1] effect on male turkey feed conversion ratio (FCR).

			Age (wk)			
Poult source	0−4	0−7	0−10	0−13	0−16	0−19
			(Experiment 1)			
L1	1.373	1.456	1.651	1.805	1.982[b]	2.179[a]
L2	1.473	1.498	1.704	1.836	2.050[a]	2.151[ab]
L3	1.470	1.482	1.646	1.808	2.0629[a]	2.174[a]
L1H[2]	1.382	1.480	1.687	1.852	2.084[a]	2.068[b]
L2H[3]	1.458	1.466	1.685	1.824	1.982[b]	2.097[ab]
SEM[4]	0.046	0.003	0.017	0.014	0.017	0.025
P-value	0.061	0.613	0.061	0.140	<0.0001	0.008

			Age (wk)			
Genetic line	0−4	0−7	0−10	0−13	0−16	0−19
			(Experiment 2)			
L1H2	1.404	1.447[b]	1.574[b]	1.767[b]	1.960[ab]	2.017
L2	1.463	1.471[ab]	1.605[ab]	1.788[ab]	1.949[b]	2.080
L4	1.452	1.488[ab]	1.653[a]	1.814[ab]	1.997[ab]	2.041
L5	1.484	1.537[a]	1.650[a]	1.804[ab]	1.995[ab]	2.084
L6	1.468	1.500[ab]	1.629[ab]	1.783[ab]	1.988[ab]	2.088
L7	1.445	1.500[ab]	1.647[ab]	1.811[ab]	1.970[ab]	2.128
L8	1.437	1.470[ab]	1.592[ab]	1.837[a]	2.023[a]	2.065
SEM[5]	0.030	0.025	0.019	0.02	0.023	0.052
P-value	0.430	0.053	0.002	0.014	0.048	0.603

			Age (wk)			
Genetic line	0−4	0−7	0−10	0−13	0−16	0−19
			(Experiment 1&2 comparison)			
L1 Exp 1	1.421	1.476	1.687[a]	1.847[a]	2.080[a]	2.088[ab]
L1 Exp 2	1.402	1.446	1.573[c]	1.768[b]	1.960[b]	2.019[b]
L2 Exp 1	1.374	1.458	1.650[ab]	1.805[ab]	1.984[b]	2.181[a]
L2 Exp 2	1.468	1.470	1.1605[bc]	1.787[b]	1.946[b]	2.081[ab]
SEM[6]	0.046	0.017	0.013	0.011	0.018	0.038
P-value	0.309	0.579	<0.0001	0.0004	<0.0001	0.014

[a,b,c]Means within a column lacking a common superscript differ ($P \leq 0.05$).
[1]Genetic lines (L) with different numbers have different genetic characteristics and traits.
[2]Poults from genetic line one sourced from a commercial hatchery.
[3]Poults from genetic line two sourced from a commercial hatchery.
[4]Maximum observed standard error of the mean for a min of n = 9 replicates and up to n = 10, 6 degrees of freedom.
[5]Maximum observed standard error of the mean for a min of n = 4 replicates and up to n = 10, 4 degrees of freedom.
[6]Maximum observed standard error of the mean for a min of n = 9 replicates for all treatments, 3 degrees of freedom.

Table 9. Poult source and genetic line[1] effect on male turkey carcass and parts yield (kg).

Poult source	BW[2]	CCY[3]	MAJ[4]	MIN[5]	TOT[6]	Wings	TG[7]	Legs	FR[8]
					(Experiment 1)				
L1	19.76	34.91	9.21	1.79	11.23	3.60	5.66	4.26	4.55
L2	19.75	35.29	9.32	1.75	11.34	3.60	5.72	4.37	4.54
L3	19.73	35.26	9.37	1.78	11.40	3.58	5.61	4.31	4.45
L1H[9]	19.70	34.92	9.24	1.78	11.26	3.63	5.63	4.25	4.42
L2H[10]	19.42	34.48	9.10	1.75	11.08	3.50	5.59	4.26	4.45
SEM	0.35	0.43	0.18	0.02	0.20	0.03	0.09	0.08	0.07
P-value	0.87	0.61	0.75	0.63	0.72	0.10	0.82	0.74	0.48
					(Experiment 2)				
L1H2	21.50[ab]	16.98[ab]	4.46[bc]	0.83[b]	5.41[bc]	1.71[ab]	2.76[ab]	2.07[ab]	2.15
L2	22.02[a]	17.28[a]	4.72[a]	0.89[a]	5.75[a]	1.76[a]	2.79[ab]	2.08[a]	2.15
L4	21.42[ab]	16.85[ab]	4.39[ab]	0.86[ab]	5.70[ab]	1.65[b]	2.67[bc]	1.99[bc]	2.08
L5	20.59[b]	16.21[b]	4.42[c]	0.78[b]	5.32[c]	1.68[b]	2.58[c]	1.93[c]	2.07
L6	20.86[b]	16.56[ab]	4.51[b]	0.82[b]	5.35[c]	1.63[b]	2.68[bc]	2.00[bc]	2.13
L7	20.95[ab]	16.61[ab]	4.61[bc]	0.86[ab]	5.49[abc]	1.66[b]	2.62[c]	2.00[bc]	2.07
L8	21.59[ab]	16.86[ab]	4.77[abc]	0.87[ab]	5.60[abc]	1.76[a]	2.82[a]	2.12[a]	2.15
SEM	0.26	0.48	0.10	0.16	0.11	0.02	0.05	0.03	0.03
P-value	0.02	0.03	0.04	0.04	0.04	0.001	0.04	0.01	0.06
					(Experiment 1&2 comparison)				
L1 Exp 1	19.78[b]	15.88[c]	4.19[b]	0.82	5.11[b]	1.64[b]	2.58[b]	1.94[b]	2.05[b]
L1 Exp 2	21.54[a]	17.02[a]	4.50[a]	0.83	5.44[ab]	1.71[a]	2.76[a]	2.07[a]	2.15[a]
L2 Exp 1	19.85[b]	16.08[b]	4.28[b]	0.8	5.21[b]	1.63[b]	2.60[ab]	1.99[ab]	2.06[b]
L2 Exp 2	21.84[a]	17.28[ab]	4.79[a]	0.9	5.79[ab]	1.76[a]	2.78[a]	2.06[a]	2.15[a]
SEM	0.45	0.24	0.10	0.01	0.10	0.02	0.05	0.04	0.03
P-value	0.02	0.01	0.01	0.27	0.004	0.001	0.02	0.08	0.05

[a,b,c]Means within a column lacking a common superscript differ ($P \leq 0.05$).
[1]Genetic lines (L) with different numbers have different genetic characteristics and traits.
[2]Mean body weight of processed birds.
[3]Cold carcass yield.
[4]Major breast with no skin.
[5]Minor breast.
[6]Total minor and major breast weight.
[7]Thighs.
[8]Frame weight.
[9]Poults from genetic line one sourced from a commercial hatchery.
[10]Poults from genetic line two sourced from a commercial hatchery.

Table 10. Poult source and genetic line[1] effect on male turkey carcass and parts yield (%).

Poult source	CCY[2]	MAJ[3]	MIN[4]	TOT[5]	Wings	TG[6]	Legs	FR[7]
				(Experiment 1)				
L1	80.67	26.38	5.17	32.15	10.33	16.21	12.23	12.96
L2	81.10	26.34	4.95	32.11	10.18	16.12	12.40	12.78
L3	81.26	26.67	5.07	32.42	10.20	15.92	12.20	12.68
L1H[8]	80.53	26.46	5.08	32.28	10.42	16.08	12.20	12.72
L2H[9]	80.64	26.33	5.11	32.10	10.16	16.17	12.37	12.93
SEM	0.66	0.25	0.06	0.29	0.09	0.12	0.09	0.33
P-value	0.58	0.87	0.26	0.91	0.15	0.43	0.32	0.20

Genetic Line	CCY[2]	MAJ[3]	MIN[4]	TOT[5]	Wings	TG[6]	Legs	FR[7]
				(Experiment 2)				
L1H2	78.92	26.32[c]	4.88	31.82[b]	10.07	16.34	12.16	12.70
L2	78.66	27.57[ab]	5.16	33.27[ab]	10.15	16.11	11.93	12.57
L4	78.70	28.00[a]	5.15	33.82[a]	9.88	15.84	11.79	12.38
L5	78.72	27.05[abc]	5.12	32.85[ab]	10.16	15.93	11.89	12.82
L6	79.46	26.72[bc]	4.98	32.31[b]	10.14	16.16	12.04	12.91
L7	79.37	27.06[abc]	5.17	32.98[ab]	9.86	15.80	12.00	12.50
L8	79.35	26.94[abc]	5.12	32.67[ab]	10.25	16.36	12.33	12.54
SEM	0.39	0.29	0.08	0.36	0.11	0.15	0.12	0.22
P-value	0.58	0.01	0.14	0.01	0.14	0.10	0.09	0.22

Genetic line	CCY[2]	MAJ[3]	MIN[4]	TOT[5]	Wings	TG[6]	Legs	FR[7]
				(Experiment 1&2 comparison)				
L1 Exp 1	80.52	26.32[b]	5.13	32.10[b]	10.36	16.25	12.20	12.95
L1 Exp 2	79.06	26.40[ab]	4.9	31.91[b]	10.01	16.22	12.10	12.63
L2 Exp 1	81.51	26.36[ab]	4.96	32.08[b]	10.16	16.21	12.40	12.75
L2 Exp 2	78.51	27.65[a]	5.18	33.43[a]	10.01	16.03	11.90	12.85
SEM	0.81	0.28	0.06	0.28	0.80	0.13	0.10	0.17
P-value	0.10	0.045	0.06	0.03	0.90	0.78	0.15	0.09

[a,b,c]Means within a column lacking a common superscript differ ($P \le 0.05$).
[1]Genetic lines (L) with different numbers have different genetic characteristics and traits.
[2]Cold carcass yield.
[3]Major breast with no skin.
[4]Minor breast.
[5]Total minor and major breast weight.
[6]Thighs.
[7]Frame weight.
[8]Poults from genetic line one sourced from a commercial hatchery.
[9]Poults from genetic line two sourced from a commercial hatchery.

Table 11. Mean ambient environmental conditions for both experiments in F for the year 2019.[1]

[2] Month	Maximum	Average	Minimum	Dew point
	Experiment 1			
January	51.29	42.19	33.00	30.53
February	57.32	47.23	38.04	36.16
March	58.90	49.09	39.55	34.28
April	71.83	61.91	51.93	50.52
May	83.61	73.13	61.45	61.29
June	85.43	75.31	66.43	64.13

[3] Month	Maximum	Average	Minimum	Dew point
	Experiment 2			
July	91.42	80.13	70.97	68.22
August	87.84	76.58	68.58	68.15
September	78.53	69.87	62.60	62.99
October	76.39	65.35	55.29	56.39
November	57.87	47.74	38.13	37.35
December	57.52	47.51	37.81	38.00

[1]Data was collected from Weather Underground (The Weather Company, IBM, Atlanta, GA) Using the Raleigh-Durham International Airport Station (10 miles or 16 kilometers from the research facility).
[2]The placement of Experiment 1 was on January 17, 2019, and ended on May 28, 2019.
[3]The placement of Experiment 2 was on July 29, 2019, and ended on December 16, 2019.

the second experiment, there was still a BW difference between treatments carried from earlier BWG. However, given enough time, with the same nutritional and environmental conditions, every bird source can achieve the same performance but not necessarily in the same amount of time. The key may be identifying the bird source parameters, even at the hatchery level, to achieve specific time and performance goals.

The results herein show the effects of the season on genetic lines. A comparison between L1 and L2 genetic lines during the spring and fall can be made because the experiments were run under the same housing, management, and nutrition conditions during the same year. Environmental temperatures based on the Raleigh-Durham international airport weather station are provided in Table 11. Based on this environmental data, the hypothesis can be made that when the genetic lines were raised in the spring ending with summer-type weather, the growth rate in terms of BWG, BW, and FI at the beginning of the trial is higher than the birds raised in the fall. However, by the end of the growth period, birds raised in the fall were approximately 2 kg, on average, heavier than their spring counterpart. This live performance

difference was also observed in the major pectoralis and total breast muscle processing yield.

Higher performance at the start (Spring) or finishing (Fall) was potential because of the greater ability to control the heat in winter than in summer in double-sided curtain houses. Summer could indeed benefit the first weeks of placement for turkeys. However, if it is prolonged, in the case of birds placed in July, it could cause heat stress in the middle of the production. Performance decrease also happens at the end of production, when birds placed in January must endure May's heat stress when they are the heaviest and probably plateau in their growth. Turkeys performance increases in terms of BWG and breast meat yield when reared in cooler temperatures rather than warmer temperature environments (Case et al., 2010). Heat stress can produce oxidative stress (Akbarian et al., 2016), reduce voluntary feed intake, and reduce BWG (Sahin et al., 2001). An increase in global temperatures and its effects on poultry production efficiency may be prioritized when selecting genetic characteristics (Kumar et al., 2021). Environmental controlled poultry housing could mitigate the increase in environmental temperature. However, this type of housing is not yet the industry standard for turkey production in the United States, and it will take longer to be adopted in developing countries because of costs.

Currently, preferred poultry industry selection traits as higher growth rates and improved FCR. For example, lines L1 and L2 are and F1 cross composed of at least 3 different pedigree lines each. Usually in turkeys, the father of the commercial is a pure line selected for commercial traits (growth rate, feed efficiency, and yield) and fitness, while the mother is a 2-way cross of 2 female lines selected for commercial traits, fitness traits, and reproductive traits. However, higher growth rates are undesirable when dealing with heat stress (Emmans and Kyriazakis, 2000; Yahav, 2000) unless mitigated through management such as environment controlled housing. The heat stress seems to be handled more efficiently by the L2 genetic line by having similar FCR regardless of the experiment. However, BW, BWG, and breast meat yields are affected by the season regardless of the genetic lines. Case et al. (2010) reviewed the factors that affect breast meat yield in turkeys. Breast meat yield increases with the hyperplasia and hypertrophy of the muscle determined by the strain and inheritance traits. However, to fulfill the genetic potential, the hatchery ventilation and temperature, nutrition, lighting program, and growth temperature has to be considered.

In conclusion, the source of the poults (hatchery) and production season (spring or fall) are vital in double-sided curtain houses even when the same genetic line, housing, management, and nutrition plan. Although farmers might have limited decision power on the genetic lines and hatchery sources, this paper provides information that can be used to improve the systems that affect farmers.

DISCLOSURES

The authors declare no conflicts of interest.

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