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Comparison of growth performance of Berkshire purebreds and crossbreds sired by Hereford and Tamworth breeds raised in alternative production system

Hyeon-Suk Park[1], Kristal Spann[1], Niki Whitley[2], and Sang-Hyon Oh[1,*]

* **Corresponding Author:** Sang-Hyon Oh
Tel: +1-336-285-4807, **Fax:** +1-336-334-7288,
E-mail: syshoh@gmail.com

[1] Department of Animal Sciences, College of Agriculture and Environmental Sciences, North Carolina Agricultural and Technical State University, Greensboro, NC 27410, USA
[2] Department of Agricultural Sciences, Fort Valley State University, Fort Valley, GA 31030, USA

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Objective: The objective of the present study was to compare growth performance of Berkshire purebred pigs (BB), Hereford (HB) and/or Tamworth (TB) sired Berkshire crossbred pigs reared in a hoop structure in two experiments.
Methods: In the first experiment, BB was compared to TB while HB and TB were compared in the second. Body weights (BW) were recorded at 3 days of age and every 28 days from birth until 140 days of age. There was no significant difference between the BW of BB and TB, but HB was heavier than TB by 84 days of age. Least square means of average daily gain (ADG) were evaluated using one-way analysis of variance.
Results: The mean parity (±standard deviation) of the sows was 3.42±2.14 and a total of 45 farrowing occurred from year 2012 to 2014. The mean number of total born, number born alive, number of mummies, and number weaned were 9.23±2.52, 7.87±2.53, 0.04±0.21, and 5.94±2.74, respectively. Parity did not have a significant effect on the growth performance of the pigs. For BB and TB, there was only one time frame in which there was a significant difference in the ADG: between 28 and 56 days of age. For HB and TB, the overall ADG of HB was significantly greater than the total ADG of TB.
Conclusion: The breed of the sire did not affect the growth performance of the progeny between Berkshire purebreds and Tamworth×Berkshire crossbreds. The breed of the sire did have an effect between Hereford and Tamworth sired Berkshire crossbreds ($p<0.05$). The Hereford sired pigs were found to have increased growth performance compared to Tamworth sired.

Keywords: Berkshire; Pigs; Crossbreds; Growth; Alternative Production System

INTRODUCTION

There are growing health and welfare concerns when it comes to human consumption of meat products which has resulted in an increased interest in meat from livestock raised in alternative production systems, including those that are organic, natural and/or outdoor. However, there are quite a few production challenges that face farmers within these systems, including the inability to control climatic conditions and a greater amount of labor needed to produce the same number of animals as a confinement system which can impact animal growth and productivity and overall profit. To make outdoor/alternative production more profitable, an added value to the pork from pigs raised outdoors must be created.

One of the ways in which value can be added to meat products from animals alternatively raised is by improving the quality of the meat while increasing the growth performance of the animals. It has been stated that certain breeds of pigs perform better in different environments than others [1]. Breed type can also influence meat quality [2], so with the various selective traits that certain breeds possess, an inquiry on how to preserve and improve on these traits arises. Heterosis

from crossbreeding may result in attaining both high meat quality and growth performance of the animals. Suzuki et al [3] reported that crossbreeding between Berkshire and Duroc largely influenced the quality of the meat compared to the purebreds, and Cassady et al [4] reported the effect of heterosis significantly increased weights throughout the periodic measures of growth performance in pigs. The Berkshire breed has been known to have superior meat quality because of the higher proportion of neutral lipid fatty acids and marbling fat which assists with palatability traits such as tenderness and juiciness [5], but the breed is not necessarily known for growth performance. So, the objective of the present study was to increase the overall value of pork from the Berkshire pigs raised in an alternative production system by improving growth performance, measured in terms of body weights (BW) and average daily gain (ADG), through crossbreeding with Hereford and Tamworth breeds.

MATERIALS AND METHODS

Meteorological data

The experiment was conducted at the Swine Unit at North Carolina Agricultural and Technical State University (NCA&T). The NCA&T swine unit is located in Greensboro, NC, where the summers are hot and humid and winters are mild. According to the U.S. Climate data, it's reported that Greensboro gets an average annual precipitation of 107 cm. The mean monthly precipitation, as well as the average, maximum and minimum temperatures by month, are provided in Table 1 for the 2-year period from 2014 to 2015, during which the experiments took place.

Herd management and data collection

At NCA&T, the sows used for breeding are raised free of antibiotics in an outdoor hoop structure until the last month of pregnancy when they are moved to a pasture-based unit of 0.8 hectares with individual lots (14×24 m^2) with a farrowing hut, shade, and water *ad libitum*. Two experiments were conducted. In 2014, Berkshire×Berkshire (BB) were compared to Tamworth×Berkshire (TB), and in 2015, TB were compared to Hereford×Berkshire (HB). Piglets were weaned at 4 weeks of age and housed in a deep-bedded hoop structure, grouped by sex. The boars were not castrated. The piglets were given access to standard NRC feed and water *ad libitum*. The nutritional information for the feed used in the different stages of production is provided in Table 2. During gestation, the sows were provided 2.27 kg of feed every morning. The BW were recorded at 3 days of age and every 28 days from birth until 140 days of age. In the first experiment, 4 sows farrowed 20 BB pigs, which resulted in a total of 172 growth performance (GP) records and 6 sows farrowed 50 TB pigs, which resulted in a total of 257 GP records. In the second experiment, 7 sows farrowed 25 HB pigs and 4 sows farrowed 27 TB pigs, each resulting in a total of 128 and 135 GP records, respectively.

Data adjustment and statistical analysis

The BW records were not always measured exactly on schedule due to unforeseen circumstances, such as extreme sow aggressiveness, inclement weather and so forth. Therefore, adjustments were made to conform the age on which the BW were recorded. Growth curve was fitted for each individual with the measured BW and the days of age on which the actual measurements were taken. Then, using polynomial regression, BW on days 3, 28, 56, 84, 112, and 140 were estimated. The power of the polynomial was determined by the number of observations each individual had. Any adjusted BW that did not meet the following conditions were discarded: i) the estimated BW is greater than the measured BW when the desired days of age is greater than the actual days of age and ii) the estimated BW is smaller than the measured BW when the desired days of age is smaller than the actual days of age. Least square means of BW were estimated with Proc Mixed in SAS 9.3 for the following fixed effects: boar breed and boar breed by day of age interaction. Least square means of ADG were compared using one-way analysis of variance with boar breed as a fixed effect. Sex effect was not included in the ADG evaluation due to the lack of significance.

Table 1. Basic monthly meteorological information for North Carolina

Month	Temperature (°C)			Average precipitation (mm)
	Average	Max	Min	
January	2.2	9.2	–5.0	76.45
February	3.3	11.1	–4.4	62.23
March	8.8	16.8	0.3	89.92
April	15.5	21.8	8.6	86.36
May	21.1	27.2	14.5	72.14
June	25.4	31.5	19.3	64.26
July	25.8	31.8	19.7	77.47
August	24.6	30.4	19.2	120.90
September	22.0	27.4	17.1	108.46
October	15.8	22.8	9.5	79.50
November	9.8	17.5	1.3	128.78
December	9.3	16.9	1.7	112.52

Table 2. Nutritional information of the different types of feed used in the experiment

Ingredients	Production phase				
	Sow		Pig		
	Gestating	Lactating	Starter	Grower	Finisher
Crude protein (%)	13.00	15.00	20.48	16.00	15.00
Lysine (%)	0.56	0.81	1.20	0.76	0.90
Crude fat (%)	3.00	6.00	5.40	3.50	3.30
Crude fibers (%)	5.00	5.00	4.00	4.10	5.00
Calcium (Ca) (%)	1.43	1.45	1.22	1.15	1.08
Phosphorus (P) (%)	0.70	0.70	0.60	0.55	0.54
Salt (NaCl) (%)	0.80	0.90	0.65	0.75	0.75
Selenium (Se) (ppm)	0.30	0.30	0.30	0.30	0.30
Zinc (Zn) (ppm)	160	150	150	120	110

Table 3. Least square means of body weights of Berkshire pigs sired by Berkshire and Tamworth[1)]

Breed	ADG	Day of age						SEM
		3	28	56	84	112	140	
Berkshire	0.55	1.79(29)	7.75(29)	16.40(29)	31.21(29)	51.49(29)	79.22(27)	1.22
Tamworth	0.55	2.00(44)	7.92(44)	18.02(44)	33.81(44)	52.18(43)	80.01(38)	1.3

ADG, average daily gain; SEM, standard error of the mean.
1) Number of observations provided in the parenthesis.

RESULTS

In the first experiment, the average numbers of total born (TBN), born alive (NBA), born dead (NBD), and weaned (NW) were 10.50±2.07, 8.80±3.05, 1.70±1.50, and 7.30±2.80, respectively. The average litter weights at birth and at weaning were 1.82±0.32 kg and 7.84±1.67 kg, respectively. In the second experiment, the average TBN, NBA, NBD, and NW were 8.58±3.15, 5.00±2.52, 3.33±2.06, and 4.42±2.57, respectively. The average litter weights at birth and at weaning were 1.97±0.46 kg and 8.33±1.47 kg, respectively.

When the measured BW records were plotted against the day on which they were taken, the individual plots resulted in a linear relationship. When the plotted points and their polynomial regression were used to estimate the BW on the desired days of age, all of the estimated BW met the given conditions.

The breed of the sire did not have a significant effect on growth of the piglets between BB and TB in the first experiment ($p>0.05$), but it did have a significant effect on the GP of the piglets in the second experiment, where the piglets were sired by Hereford and Tamworth breeds ($p<0.001$). The least square means of the BW of BB and TB from the first experiment are presented in Table 3. Though there seemed to be a numerical difference, there was no statistically significant difference in BW for BB and TB (Figure 1). For the ADG, presented in Table 4, there was only one time frame, during which TB was higher than BB: between 28 and 56 days of age. Between 84 and 140 days of age, the ADG of BB was higher than the ADG of TB. However, statistically significant difference did not exist for all other time frames, including the overall ADG from birth to 140 days of age. For HB and TB (Table 5), BW was different on day 84 through 140 days of age ($p<0.05$). By day 84, HB was heavier than TB by approximately 6.5 kg. The difference in BW increased as days of age increased so that by 140 days of age, the difference in BW between HB and TB was approximately 9 kg (Figure 2). Furthermore, there was a significant difference between the overall ADG of HB and TB ($p<0.05$). The overall ADG of HB was greater than that of TB, even though their periodic ADG did not differ.

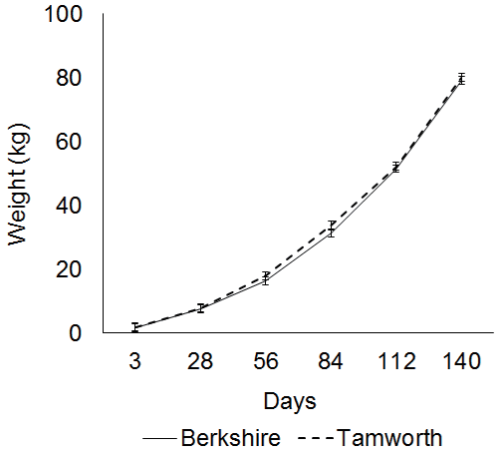

Figure 1. Least square means and standard errors of body weights of Berkshire pigs sired by Berkshire and Tamworth.

Table 4. Least square means of average daily gain of Berkshire purebreds (BB) and crossbreds sired by Hereford (HB) and Tamworth (TB)

		Days of age					Total
		3 to 28	28 to 56	56 to 84	84 to 112	112 to 140	
Trial 1	BB	0.24	0.31[a]	0.53	0.72	0.97	0.57
	TB	0.25	0.35[b]	0.60	0.70	0.92	0.58
	SEM	0.07	0.08	0.16	0.17	0.14	0.07
Trial 2	HB	0.33	0.38	0.72	0.73	0.99	0.63[a]
	TB	0.23	0.31	0.58	0.72	0.90	0.58[b]
	SEM	0.10	0.12	0.14	0.12	0.18	0.09

SEM, standard error of the mean.
[a,b] Least square means in the same column with different superscripts differ ($p<0.05$).

Table 5. Least square means and number of observations of body weights of Berkshire pigs sired by Hereford and Tamworth[1)]

Breed	ADG	Day of age						SEM	p value
		3	28	56	84	112	140		
Hereford	0.63	2.36(20)[a]	9.74(22)[a]	20.28(22)[a]	40.47(22)[a]	60.83(21)[a]	88.67(21)[a]	1.51	<0.0001
Tamworth	0.52	1.78(25)[a]	7.48(25)[a]	16.35(24)[a]	32.89(23)[b]	54.30(19)[b]	79.63(19)[b]	1.45	<0.0001

ADG, average daily gain; SEM, standard error of the mean.
[1)] Number of observations provided in the parenthesis.
[a,b] Least square means in the same column with different superscripts differ ($p<0.05$).

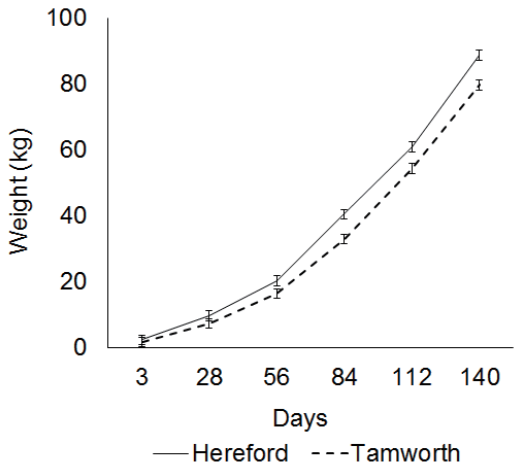

Figure 2. Least square means and standard errors of body weights of Berkshire pigs sired by Hereford and Tamworth.

DISCUSSION

A number of growth equations are available that describe the relationship between BW and day of age for pigs. Some of the most commonly used equations are Gompertz, Logistics, von Bertalanffy, Richards, Bridges, Generalized Michaelis-Menten and Polynomials. These equations allow commercial producers to predict the live weight of pigs from birth to maturity, providing many economic advantages. However, the purpose of the growth curve used in the present study was different from its general usage. The purpose of growth curve modeling in the present study was to adjust the BW of the individuals according to their actual measurements, which were taken on different days of age due to unforeseen circumstances such as an inclement weather condition, to conform the age on which the measurements were recorded. Research on outdoor production can be unpredictable. The experimental design was to record BW every 4 weeks from birth to harvest; however, inclement weather conditions such as heavy rain or snow prevented the weighing of the animals on exact dates. Therefore, the recorded data was adjusted to standardize the data points on 3, 28, 56, 84, 112, and 140 days of age.

Using the most commonly used growth equations to plot the BW of pigs from birth to maturity will draw an S-shaped curve. In an S-shaped curve, the rate of growth of the animals begins to decrease and eventually reaches zero as the BW of the animals approach maturity. At this point, keeping the animals to sell as meat products becomes unprofitable because of the low feed efficiency. For this reason, commercial producers sell their animals when the growth rate, and thus the feed efficiency, of the animals are maximal. Because the animals never reached their maturity, their growth did not result in an S-shaped curve. Instead, when their BW records are plotted against the days of age on which the records are taken, a linear relationship was observed. Thus, applying the most commonly used growth equations to plot an S-shaped curve for the BW of the animals used in this study was inappropriate. Considering the short lifespan of the animals used, polynomial regression was used to adjust the BW of the individual animals on the desired day of age. This was based on other studies where polynomial functions were reported as providing accurate estimates of live BW of pigs. According to Shull [6], simple polynomial or logarithmic equations to provide more accurate estimates between live weight and periodic measures of growth performance in pigs. Furthermore, polynomials fit very well when the appropriate number of terms is chosen [7]. Kohn et al [8] also reported linear polynomials of third and fourth order of fit as the best fit for BW data in the minipig.

Berkshire pigs are known for their superior meat quality but inferior reproductive and growth performances. Because of the low reproductive and slow growth performances, Berkshires have limited value in commercial swine industry, but make an attractive alternative for producers interested in raising premium pigs. Studies have shown that the effect of heterosis significantly increases weights throughout the periodic measures of growth performance in pigs [4]. Numerous studies on the performances of Berkshire pigs can be found in East Asia, where a niche market is well established for their high quality meat. Sasaki et al [9] reviewed the reproductive performance of the purebred Berkshire breed in Japan and found average birth (1.4 3±0.13 kg) and weaning weights (7.30±0.70 kg) that were similar to those found in the present study. Suzuki et al [3] reported that crossbreds produced by crossing Berkshire boars to Duroc–Landrace sows (LDB) had faster growth rates than Berkshire purebreds (BB). Though direct comparison was not possible due to the difference in methods of measurement, the growth rate of BB reported by Suzuki et al [3] was similar to that of the present study. In both studies, BB reached approximately 30 kg around 80 days of age. The LDB reached 30 kg significantly earlier than BB (69.5 days of age). However, the days of age on which Duroc purebreds, LDB, and LDD (produced by crossing Duroc boars to Duroc–Landrace sows) reached 30 kg did not significantly differ ($p>0.05$).

In North America, a limited amount of research was available that studied the effects of crossbreeding swine on the growth performance of the progeny, and even fewer amount of studies looked at Berkshire crossbreds. Fahmy and Bernard [10] evaluated 28 different crossbreds resulting from mating 7 different breeds of sows with 7 different breeds of boars. Berkshire was included among the breeds of sows and boars used in the study, and Tamworth was included among the breeds of boars. According to Fahmy and Bernard [10], crosses among Berkshire and Tamworth breeds, along with the Large Black, were the poorest. Crosses between Tamworth boars and Large Black sows ranked the last among the 28 different crossbreds. Whitley et al [11] performed a study similar to the present study, comparing the growth performance of Yorkshire purebreds (YY) and crossbreds sired by Berkshire (BY), Large Black (LBY), and Tamworth (TY) breeds raised in hoop structures. In their study, though ADG and overall

litter birth and weaning weights were not influenced by breed of sire ($p>0.05$), the average birth weight of the purebreds was lower than the averages of birth weights for the crossbreds. Furthermore, the average of birth weight for BY was lower than TY (LBY intermediate), but individual weaning weights were higher for BY and LBY than TY ($p<0.05$). By 150 days of age, the BW of TY was the smallest among the four breeds, indicating slow growth for crossbreds sired by Tamworth, which is similar to the results of the present study. The slow growth of Tamworth breeds is also reported by Wood et al [12]. Even though the ADG reported by Woods et al [12] are much lower than the ADG reported in the present study due to the differences in feeding regimes (restricted vs *ad libitum*), it clearly showed that Berkshire and Tamworth breeds had slower growth compared to Duroc or Large White breeds. The same study also showed that the overall pork flavor and flavor liking was higher for the Berkshire and the Tamworth breeds. Crossbreeding Berkshire and Tamworth breeds may result in a superior meat quality and provide an added value for the farmers, but their slow growth makes such crossbreeding unfavorable. Crossbred studies including the Hereford breed were not found. The superior growth of HB breed found in the present study needs to be verified through further study.

CONCLUSION

Polynomial regression effectively drew an appropriate growth curve that accurately estimated the adjusted values of BW of the pigs. The breed of the sire did not affect the growth performance of the progeny between Berkshire purebreds and TB crossbreds. The breed of the sire did have an effect between Hereford and Tamworth sired Berkshire crossbreds ($p<0.05$). The Hereford sired pigs were found to have increased growth performance compared to Tamworth sired. Due to the limited amount of research on the effect of crossbreeding on the growth performance of Berkshire pigs, comparing the results of the present study to those of other studies was difficult. Further study with different breeds of sire is needed to find the breed of pigs with the best growth performance when crossbred with Berkshire sows.

CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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