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Using Artificial Insemination for Mating Sows to Heritage Breed Boars to Produce Crossbred Hogs Suitable for Niche Market Pork: A Demonstration Study

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From 1982 to 2002, rapid consolidation and vertical integration of pork production resulted in an 84% decrease in the number of Virginia farms selling hogs and pigs (fig. 1). Since 2002, the number of pig farms in Virginia has stabilized at approximately 1,000.

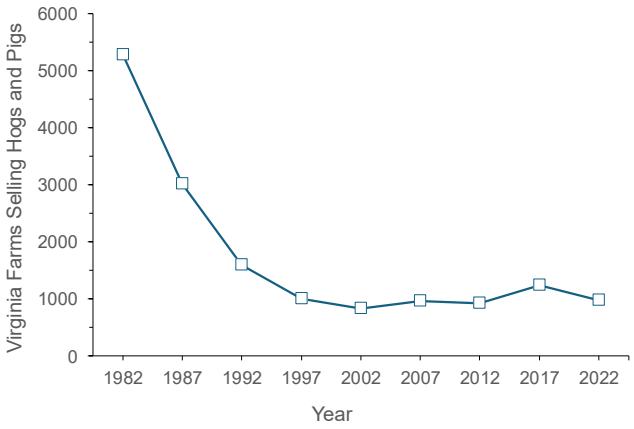

Figure 1. Number of farms in Virginia with sales of hogs and pigs for the period from 1982 to 2022. Data is from the U.S. Department of Agriculture Census of Agriculture (https://www.nass.usda.gov/AgCensus/) conducted in 1982, 1987, 1992, 1997, 2002, 2007, 2012, 2017, and 2022.

However, of the more than 700,000 hogs and pigs annually produced in Virginia, over 94% are from less than 60 large-scale, integrator-owned or contract operations each selling more than 1,000 head each year (Estienne 2023). The remaining hogs and pigs are raised on more than 900 small-scale and niche-market type farms, focused on a segment of consumers with interest in pork from hogs raised locally in less intensive systems and with certain attributes such as "reared outdoors with no antibiotics." Data from the USDA indicates that more than 84% of direct-to-customer farm sales occur in counties immediately adjacent to large metropolitan areas (Martinez et al. 2010). If niche market pork production continues to flourish nationally and in Virginia, the markets and the farmers that supply them will remain a viable entity in a diverse agriculture (Honeyman et al. 2006).

Many different breeds of pigs are raised on niche market farms, but interest in heritage swine is increasing. Heritage swine are purebred animals with a long history in U.S. agriculture, but because of their small numbers, they are considered endangered. The Livestock Conservancy (https://livestockconservancy.org/), provides the current Conservation Priority List of Heritage Swine:

- Critical — Choctaw, Large Black, Mulefoot, and Ossabaw Island.
- Threatened — Gloucestershire Old Spots, Guinea Hog, Meishan, and Red Wattle.
- Recovering — Tamworth.

From the farmer's viewpoint, heritage breeds are hardy and adaptable animals that work well in outdoor environments. Moreover, many chefs and consumers consider pork from heritage swine to be superior in taste, texture, and nutritional content compared to commodity pork purchased in local grocery stores. Compared with commercial hogs, however, heritage swine put on more fat and have lighter muscling, which may not appeal to some consumers.

When determining which breeds of swine to use, farmers must consider traits important to the production system to be used and the targeted customers. For the niche market pig farmer selling animals for local slaughter and harvest of pork, there is no requirement for purebred stock and so crossbred market hogs can

work very well, as they do for other segments of the commercial swine industry. The objective of this study was to demonstrate the use of artificial insemination (AI) and crossbreeding principles to produce hogs suitable for niche market pork production.

Materials and Methods

Selection and Justification of Breeding System and Breeds

Crossbreeding was used in this study because it offers two primary advantages:

1. Hybrid vigor (or heterosis), which is the improved performance of crossbred offspring compared to the average of their purebred parents.

2. Breed complementarity, which allows a breeder to blend the superior traits of one animal with the superior traits of another animal into their crossbred offspring.

In this study, Duroc sows were mated to Berkshire boars using AI, producing F1 sows. "F1" refers to the first generation of offspring resulting from crossing two different purebred swine. According to the Pork Checkoff (https://porkcheckoff.org/pork-branding/facts-statistics/major-swine-breeds/), the Berkshire breed is recognized for excellent meat quality and is extensively employed in niche market pork production, while the Duroc is known for excellent growth performance and carcass characteristics, and is routinely used in modern, commercial breeding systems.

Six Berkshire by Duroc crossbred sows were bred by AI to produce the pigs evaluated in this study. Semen was obtained from three different Heritage Breed Boars: Gloucester Old Spots, Red Wattle, and Tamworth. Gloucester Old Spots are hardy and are known for their docility and prolificacy. Red Wattle pigs are recognized for their relatively rapid growth rate and carcasses that produce well-marbled, flavorful meat. The Tamworth was traditionally considered a "bacon" breed because it grew slowly and produced meat and bacon that was lean and fine-grained. According to The Livestock Conservancy, hogs of this breed have fine bones, and carcass yields (or dressing percentage, defined as [dressed carcass weight ÷ live weight] × 100) of up to 70%.

Study Protocol

The study was conducted at the Tidewater Agricultural Research and Extension Center in Suffolk, and the experimental protocol was reviewed and approved by the Institutional Animal Care and Use Committee at Virginia Tech.

Animal Husbandry

Duroc by Berkshire crossbred sows were bred by AI using Gloucester Old Spots, Red Wattle, or Tamworth semen purchased from a commercial boar stud (International Boar Semen, Eldora, Iowa). Boars (castrated at 7 days of age) and gilts representing each of the three sire breeds were born on the same day in traditional farrowing crates, and a total of 23 pigs were eventually studied. In all, the Gloucester Old Spots semen sired four barrows and four gilts (fig. 2); the Red Wattle semen sired four barrows and four gilts; and the Tamworth semen sired four barrows and three gilts.

Figure 2. Pigs farrowed by a Berkshire by Duroc crossed sow and sired by a Gloucester Old Spots boar. (Photograph courtesy of Kimberly Williams, Tidewater Agricultural Research and Extension Center.)

Pigs were weaned at 21 days of age and then managed as is typical for commercial swine production in confinement facilities. In the nursery and grow-finish phases of production, pigs were kept in environmentally controlled rooms in pens with galvanized steel bar slats

and partially slotted concrete floors, respectively. Pigs in each pen were allowed free choice access to feed via stainless steel feeders and to water through nipple drinkers. Fortified corn and soybean meal-based nursery and grow-finish diets were formulated to meet the requirements for the various nutrients (NRC 2012).

Measurements

Pigs were weighed at weaning and prior to harvest at the end of the finishing phase of production, and weight per day of age and days to 250 pounds body weight were calculated. At the end of finishing (age of pigs was 167 days), tenth rib backfat thickness was determined approximately 1.5 inches off midline using a hand-held ultrasound instrument (the Lean-meater; Renco Corporation, Minneapolis, Minnesota; http://www.rencocorp.com/product/lean-meater/).

Harvest, Carcass Fabrication, and Carcass Measurements

Hogs were harvested at a commercial facility, and hot carcass weight was determined after slaughter and skinning. Carcasses were allowed to chill overnight and vertebrae on one side cut perpendicular to the long axis of the loin between the tenth and eleventh ribs, allowing measurement of backfat thickness (measured with a ruler) and loin muscle area (measured using Grid AS-235e, Iowa State University, Ames) (Kauffman, Epley, and Carr 1992). Because carcasses were skinned, 0.1 inch was added to backfat measurements. Length of the carcass was also measured, and muscling was subjectively scored: 1 = thin (inferior); 2 = average; and 3 = thick (superior). Muscle color was scored on a six-point scale: 1 = pale pinkish gray to white; 2 = grayish pink; 3 = reddish pink; 4 = dark reddish pink; 5 = purplish red; and 6 = dark purplish red (NPPC Pork Quality Solutions Team 2006). Marbling was scored on a scale of 1 to 10 corresponding to an intramuscular fat content of 1.0% to 10.0% (Jeremiah 2006). Predicted lean was determined by dividing the estimated pounds of carcass lean by hot carcass weight and multiplying by 100. Estimated pounds of lean = 2 + (carcass weight [pounds] x 0.45) + (LMA [inches^2] x 5.0) – (fat depth [inches] x 11.0) (Ray 2015).

Statistical Analyses

Data were subjected to analysis of variance using SAS (SAS Institute Inc., Cary, North Carolina). The model included sire breed, sex, and the interaction of sire breed and sex as possible sources of variation. Carcass characteristics (carcass weight, yield, length, loin muscle area, tenth rib backfat thickness, muscling, and muscle color and marbling) were corrected for differences in body weight. Differences in means were considered statistically significant if $P \leq 0.05$ and tendencies declared if $P \leq 0.1$. Finally, actual tenth rib backfat thickness and tenth rib backfat thickness as determined ultrasonically were compared using correlation procedures.

Results and Discussion

The interaction between breed of sire and sex of pig was not statistically significant for final body weight, tenth rib backfat thickness as determined using ultrasound technology, or weight per day of age. Days to 250 pounds body weight tended ($P = 0.09$) to be affected by the breed of sire by sex interaction, as shown in figure 3.

Figure 3. Growth characterized as days to 250 pounds of body weight in barrows and gilts farrowed by Berkshire x Duroc sows and sired by Gloucester Old Spots, Red Wattle, or Tamworth Boars (n = 3 to 4/sire breed by sex combination). There was a tendency ($P = 0.09$) for an interaction of sire breed and sex on days to 250 pounds of body weight because values tended ($P = 0.09$) to be greater in barrows versus gilts for Red Wattle but not Gloucester Old Spots or Tamworth.

Sex differences in growth and carcass characteristics in swine are well documented. In general, castrated males grow faster than gilts, but at finishing weights, gilts are leaner and display less backfat (Quijandria, Woodard, and Robison 1970; Bereskin, Davey and Peters 1976; Latorre et al. 2004; Garitano et al. 2016). Consistent with these previous reports in the literature, weight per day of age was greater ($P < 0.01$) in barrows compared to gilts in the current study, and barrows required approximately nine fewer days to achieve body weights of 250 pounds ($P < 0.01$) (table 1). Additionally, backfat thickness measured ultrasonically at the tenth rib was greater ($P < 0.01$) in barrows compared with gilts. In contrast, muscling was greater ($P = 0.03$) in gilts versus barrows (table 2).

Table 1. Main effects of sire breed (Gloucester Old Spot [GOS], Red Wattle [RW], and Tamworth [TAM]) and sex (barrow or gilt) on growth characteristics in hogs.

	BREED					SEX			
ITEM	GOS	RW	TAM	SE	*P*-value	Barrow	Gilt	SE	*P*-value
Number	8	8	7	---	---	12	11	---	---
Body weight, lb	246.1[a]	254.9[a,b]	264.3[b]	6.4	**0.04**	264.8	245.4	3.7	**< 0.01**
10th rib backfat[1], in	1.21	1.28	1.21	0.09	0.71	1.39	1.08	0.05	**< 0.01**
Weight per day of age, lb	1.47[a]	1.53[a,b]	1.58[b]	0.04	**0.04**	1.59	1.47	0.03	**< 0.01**
Days to 250 lb body weight	169.2[a]	165.6[a,b]	161.0[b]	2.8	**0.03**	160.8	169.7	2.2	**< 0.01**

[1] Measured ultrasonically (Lean-meater, Renco Corporation, Minneapolis, MN) at the 10th rib.

[a,b] For items within main effect of sire breed, means with different superscripts differ ($P < 0.05$).

Table 2. Main effects of sire breed (Gloucester Old Spot [GOS], Red Wattle [RW], and Tamworth [TAM]) and sex (barrow or gilt) on carcass characteristics in hogs.

	BREED					SEX			
ITEM	GOS	RW	TAM	SE	P-value	Barrow	Gilt	SE	P-value
Number	8	8	7	---	---	12	11	---	---
Body weight, lb	238.7	247.2	250.2	5.4	0.32	256.8	233.9	4.4	**< 0.01**
Carcass weight, lb	163.5[a]	170.0[a,b]	176.6[b]	3.4	**< 0.01**	170.4	169.7	1.9	0.83
Yield, %	66.0[a]	68.8[a,b]	71.4[b]	1.2	**< 0.01**	68.9	68.5	1.2	0.73
Carcass Length, in	31.6	31.7	31.3	0.5	0.74	31.8	31.3	0.5	0.29
Loin muscle area, in^2	7.03	7.11	7.46	0.46	0.60	6.97	7.43	0.41	0.27
10th rib backfat, in	1.15	1.21	1.22	0.16	0.88	1.26	1.13	0.14	0.39
Color	3.0	3.0	2.9	0.3	0.82	3.2	2.8	0.2	0.12
Marbling	2.6	2.6	2.6	0.4	0.99	2.8	2.3	0.3	0.18
Muscling	2.1[a]	2.2[a]	2.8[b]	0.2	**< 0.01**	2.2	2.5	0.2	**0.03**
Carcass lean, %	60.1	59.4	59.6	1.6	0.87	58.5	60.9	1.4	0.11

[a,b] For items within main effect of sire breed, means with different superscripts differ ($P < 0.05$).

Three different heritage breed boars were used to produce pigs evaluated in the current study. The Gloucestershire Old Spots breed was developed in England during the 1800s, imported to the U.S. during the 1900s, and made genetic contributions to major American breeds, including Spotted Swine and Chester White. Although the origin and history of the Red Wattle breed is obscure, it is thought that it was developed in Texas. The Tamworth originated in Ireland and was imported to the U.S. in 1882 (https://livestockconservancy.org/).

In this experiment, the sire breed affected final body weight ($P = 0.04$), weight per day of age ($P = 0.04$) and days to reach 250 pounds body weight ($P = 0.03$) (table 1). For each item, values were greater ($P < 0.05$) for Tamworth compared with Gloucester Old Spots, with Red Wattle having intermediate values not statistically different from the other two breeds.

Meat from carcasses evaluated in this study was reddish pink, firm and non-exudative, and there were no cases of pork characterized as either pale, soft, and exudative, or dark, firm and dry. Carcass characteristics are shown in table 2.

Carcass weight and yield were influenced ($P < 0.01$) by sire breed and were greater ($P < 0.05$) in Tamworth compared with Gloucester Old Spots, with Red Wattle again having intermediate values not statistically different from the other two breeds. Muscling ($P < 0.01$) was affected by sire breed and was greater ($P < 0.05$) in Tamworth compared with Gloucester Old Spots and Red Wattle pigs, which did not differ. Other carcass measures, including length, loin muscle area, tenth rib backfat thickness, and carcass lean, as well as indicators of pork quality, including color and marbling, were similar among breeds. Regarding carcass traits, the interaction of breed of sire and sex affected ($P = 0.05$) only carcass length. For Gloucester Old Spots, but not

Red Wattle or Tamworth, carcass length tended to be greater ($P = 0.08$) for barrows versus gilts (fig. 4).

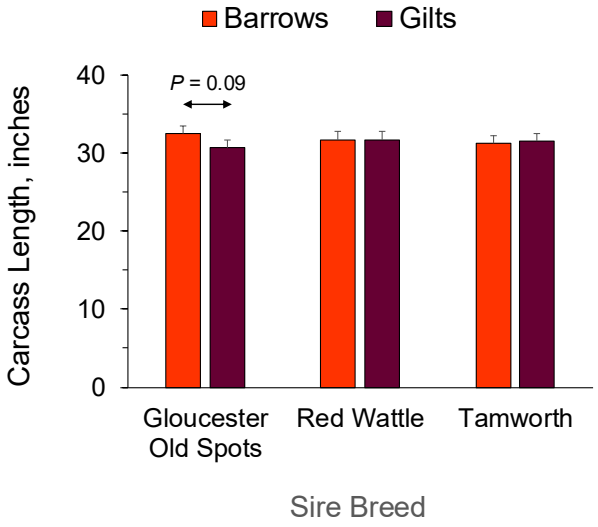

Figure 4. Carcass length in barrows and gilts farrowed by Berkshire by Duroc crossbred sows and sired by Gloucester Old Spots, Red Wattle, or Tamworth boars (n = 3 to 4 per sire breed by sex combination). The interaction between sire breed and sex was significant ($P = 0.05$) and carcass length tended to be greater ($P = 0.08$) in barrows versus gilts for Gloucester Old Spots but not Red Wattle or Tamworth.

Although little research has been conducted to assess growth performance and carcass characteristics for the various heritage breeds of swine, anecdotal evidence suggests that hogs from these genetic sources grow slower and, at harvest, have less muscle and more fat than modern, commercial market hogs. In an experiment conducted in Kentucky, seven purebred piglets from each of eight heritage breeds, including Gloucestershire Old Spots, Red Wattle, and Tamworth, were transported to Berea College (Berea, Kentucky) and grown to market weight on fescue pasture that had some other grasses and broadleaf weeds present. Three hoop shelters with deep bedding and one shade tree provided protection from sun, wind, and rain. Pigs were allowed water and a fortified, corn-soybean meal-based diet on a free-choice basis. When desired market weights were achieved, hogs were transported to the University of Kentucky (Lexington) for harvest. Tamworth pigs grew the fastest (approximately two pounds per day) and reached a market weight of 318 pounds at 6.5 to 8.5 months of age. In contrast, Gloucester Old Spots pigs weighed 247 pounds at eight to 10.5 months of age, and Red Wattle pigs weighed 300 pounds at 7.5 months of age. Hot carcass weight was 231, 224, and 156 pounds, and the carcass yield was 72.6%, 74.6% and 63.0%, for Tamworth, Red Wattle and Gloucester Old Spots, respectively. Tenth rib backfat thickness and loin muscle area was 1.8 inches and 6.1 square inches, respectively, for Tamworth; 2.1 inches and 4.5 square inches, respectively, for Red Wattle; and 1.3 inches and 5.3 square inches, respectively, for Gloucester Old Spots. A summary of these research results, Heritage Hog Carcass Yields, can be found online at https://uknowledge.uky.edu/yield_reports/.

Pigs in the current study performed well in terms of growth and reached slaughter weights of approximately 250 pounds at 167 days of age. For comparative purposes, typical wean-to-finish performance in commercial pork production is as follows: A pig weaned at 19.3 days weighing 12.8 pounds reaches a market weight of 262 pounds by 183 days of age for an overall average daily gain of 1.5 pounds (Knauer and Hostetler 2013). Overall, our experimental pigs generally produced carcasses with color and marbling within the ranges targeted by the commercial pork industry (NPPC Pork Quality Solutions Team 2006), and under the conditions of this study, Tamworth-sired pigs displayed superior growth performance and overall carcass characteristics as compared with Gloucester Old Spots- and Red Wattle-sired pigs. Previously, Park et al. (2017) reported that Tamworth by Berkshire crossbred pigs had significantly larger loin muscle area compared with Hereford by Berkshire individuals. In a study conducted in the United Kingdom, average daily gain was less, and fat thickness at the last rib was greater in Tamworth versus Duroc purebreds; Purebred Tamworth and Berkshire pigs had similar growth rates and backfat thickness (Wood et al. 2004).

Caution must be exercised when comparing results from the experiment reported here and data from the Kentucky study described above, and others. In the Kentucky research, pigs were purebred individuals reared in an extensive environment that is consistent with many small-scale or niche market pig farms. In contrast, pigs in the current study were crossbred individuals, and growth would be expected to be positively impacted by hybrid vigor. Pigs in this study were also reared in intensive confinement facilities more typical of modern commercial hog farms.

For the current experiment, backfat thicknesses over the tenth rib were determined on the live hogs using a hand-held, A-mode ultrasound instrument, and values were compared to actual tenth rib backfat thicknesses measured on the chilled carcasses. Descriptive statistics are shown in table 3.

Table 3. Comparison of tenth rib backfat thickness as determined using ultrasound or actual carcass measurements.

ITEMS	MEASUREMENT METHOD (N = 23 PIGS/CARCASSES)		
	Ultrasound, in[1]	Actual carcass, in2	Difference
Tenth rib backfat	1.24	1.20	-0.04
Standard deviation	0.23	0.27	0.04
Minimum	0.90	0.80	-0.10
Maximum	1.80	2.00	0.20

[1]Lean-meater, Renco Corporation, Minneapolis, Minn.

[2]Ruler.

There was a positive correlation (0.59; $P < 0.01$) between backfat thickness measured ultrasonically and actual carcass backfat thickness. That a higher correlation between these two estimates of fatness was not demonstrated is consistent with previous reports in the literature. Similar correlations were reported by Adams et al. (1972) (0.58; $P < 0.01$) and Cecchinato et al. (2013) (0.54; $P < 0.01$). Both research teams employed a Lean-meater ultrasound instrument like that used in the current investigation.

Implications

- This study demonstrates the efficacy of using AI in a crossbreeding program designed to capture the benefits of hybrid vigor and to capitalize on purported flavor characteristics of pork produced by heritage breed hogs, and the documented superior carcass quality and growth performance of the more conventional Berkshire and Duroc breeds. The keys to a successful AI program are detecting estrus (in other words, heat) in sows and gilts, and proper semen handling and insemination technique. The AI procedures are not difficult and can easily be mastered with some practice. County Extension agents and state swine Extension specialists are available for assistance and training.

- Pigs sired by Duroc and Berkshire crossbred sows, sired by Gloucester Old Spots, Red Wattle, or Tamworth boars, and reared in an environment like modern, commercial production systems grew well and produced carcasses with quality acceptable by current industry standards. More research is needed, however, to investigate using other heritage breeds in crossbreeding programs for small-scale pig farms and to document growth performance and carcass characteristics in pigs raised in more extensive (in other words, outdoor) environments.

- Under the conditions of this experiment, Tamworth-sired pigs displayed superior growth performance and overall carcass characteristics as compared with Gloucester Old Spots- and Red Wattle-sired pigs. Determining whether these are true breed differences or a result of the specific sires used in this study will require further research.

- A relatively inexpensive (~$709) A-Mode ultrasound instrument is reasonably reliable for determining overall backfat thicknesses in groups of live, heritage breed-sired hogs.

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