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SWINE BREEDING SYSTEMS
for Alternative Pork Chains:
Breed Options and Use

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Introduction

Multiple pork chains continue to develop within the pork industry. These differing supply chains have particular specifications for targeted markets, such as final product attributes, particular practices for animal rearing or both. To meet these varying specifications for differing pork chains, pork producers must match their production management and marketing practices to the requirements of their targeted market. This includes developing a breeding program that utilizes breed combinations that best align with the specifications of the pork chain(s) they target. This bulletin will address choosing a breeding system and breeds to use within a breeding program to meet the needs of the farm production system. When using this bulletin, producers should also have access to the Michigan State University (MSU) Extension bulletin "Breeding Systems for Alternative Pork Chains: Breeding Programs (E3107)."

Developing a Breeding System

Pork producers should choose a breeding system that best fits their needs and the resources available within the farm. To make this choice, a producer needs to answer several important questions:

- What are the performance and marketing goals of the farm?
- What breeds best fit the specifications of the target market and have characteristics that best coincide with the capabilities of the farm production system?
- Will adult animals be housed individually or in groups within gestation and/or farrowing?
- Will replacement gilts be produced internally (on the farm) or purchased?

This bulletin will address these topics.

Performance and Marketing Goals and Breed Characteristics

When establishing a breeding program, a producer must understand the overall needs and goals of the farm. This will influence the breeds or lines that are chosen and the crossing system that is implemented. The needs and goals of the farm should encompass the management and performance standards necessary to be profitable as well as meet any required marketing specifications.

Sow productivity. Regardless of the production system, more pigs weaned per litter should improve profitability. More pigs per litter allows for fixed costs (facility costs, debt service, etc.) to be spread over more units of product – i.e., pigs sold. It is reasonable to suppose that, in some extensively managed systems, too many pigs born per litter could result in high preweaning death loss. Furthermore, some prolific sow crosses do not adapt well to extensive management conditions. Therefore, maintaining prolific sow crosses under extensive management conditions could result in the number of pigs weaned per litter to be similar to or possibly even lower than with less prolific sow crosses. Figure 1 presents a summary of 1,556 farrowings from one study of two-breed F_1 crosses of various breed combinations. In general, the white breeds – primarily Yorkshire, Landrace and Chester White – should be used to improve sow productivity. Figure 1 shows that crossing one of these white breeds with a colored breed that is intermediate in expectation for litter size (i.e., Duroc and Hampshire) can result in acceptable reproductive performance that may be better suited for less intensively managed conditions.

Growth and carcass merit. Growth rate and carcass composition are often adversely related to each other. Pigs that grow fast tend to be fatter than pigs that grow slowly, though this relationship is not a strict one-to-one

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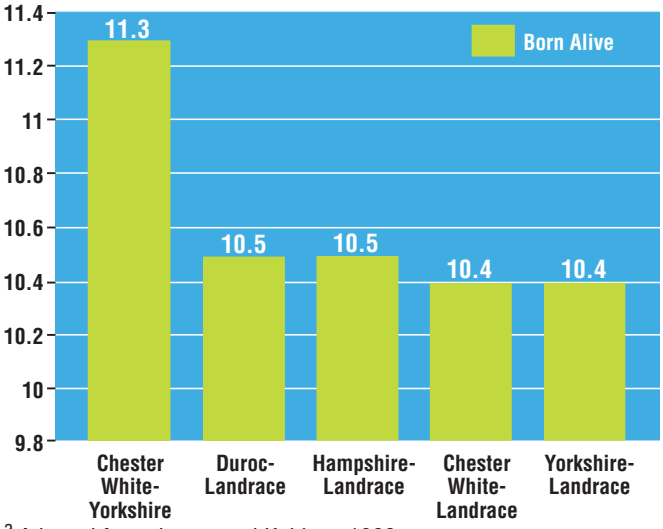
Figure 1. Number Born Alive of F_1 Sow Crosses.[a]



[a] Adapted from Jungst and Kuhlers, 1988.

relationship. Table 1 summarizes 13 years of performance information from pigs representing the traditional pure breeds that were entered into the National Barrow Show Progeny Test program (Goodwin, 2004). It shows that pigs that grew faster tended to be fatter. The fastest growing pigs were not the fattest, however. Duroc pigs were the fastest growing but were intermediate in backfat thickness and had the lowest dressing percent. Berkshire and Chester White pigs were the fattest pigs. Berkshire pigs, however, were intermediate for growth, and Chester White pigs were somewhat slower growing.

Table 1. Growth and Carcass Merit of Traditional Breeds.[a]

Breed	Average Daily Gain, lb/day	[b]Tenth Rib Backfat, in.	[c]Dressing Percent
Duroc	1.79	0.90	72.4
Landrace	1.79	0.93	73.2
Poland China	1.77	1.08	72.6
Yorkshire	1.76	0.90	73.6
Berkshire	1.74	1.13	72.8
Chester White	1.71	1.13	73.4
Spotted	1.71	1.02	73.4
Hampshire	1.68	0.85	73.0

[a] Adapted from Goodwin, 2004.
[b] Off-midline backfat thickness measured at the 10th rib.
[c] Calculated as hot carcass weight divided by off-farm weight and multiplied by 100.

Berkshire pigs were somewhat intermediate for dressing percent; Chester White pigs ranked near the top for dressing percent.

Meat quality. Meat quality can be assessed in many ways. Typically, meat quality is quantified by measuring three characteristics of the loin muscle (the muscle that is processed into pork chops): intramuscular fat percent, often referred to as marbling; pH; and color at 24 hours after harvest. Meat color is often quantified by using a meter that measures light reflectance. The reported value for light reflectance is called L*. The L* measurement has a typical range of 36 to 66. Lower values indicate darker meat (less reflectance); higher values indicate lighter colored or paler meat (greater reflectance). In the U.S., consumers typically prefer pork to be reddish pink (intermediate L* values). Consumers in Asian markets typically prefer pork to be darker red (lower L* values).

The pH is a measure of acidity or alkalinity. The range of pH values is from 1 to 14. A pH value of 7.0 is neutral – neither acidic nor alkaline. Values below 7 indicate more acidic meat, and values above 7, more alkaline. The typical range in pH values observed in pork loins 24 hours after harvest is 5.0 to 6.8. Pork loins with higher pH values tend to hold water better than those with lower pH values. This causes less drip loss or purge in the storage and display of fresh meat, and typically improves cooking and curing attributes.

Intramuscular fat percent or marbling is measured as the percent fat within the muscle. It is often thought that marbling has a relationship to flavor. Within most U.S. markets, 2 to 3 percent intramuscular fat is typically preferred in loin chops. In Asian markets, a higher percent of intramuscular fat is often desired. Overall, high quality pork loins are considered to have higher than average pH values, lower L* values (darker), and average or above average percentage of intramuscular fat.

Table 2 provides a summary from the National Barrow Show Progeny Test for loin muscle intramuscular fat percent, pH and color (represented as L*) at 24 hours after harvest. The Duroc, Berkshire and Chester White breeds had the most intramuscular fat (marbling) and the highest pH. They also tended to have darker loin chops. However, the darkest loin chops were from Hampshire pigs, even though they were intermediate for pH. Table 3 provides an assessment of breed differences for saturated fatty acids and polyunsaturated fatty

Table 2. Loin Muscle, Meat Quality Characteristics of Traditional Breeds.[a]

Breed	Intramuscular Fat Percent	pH at 24 hours after harvest	Objective Color, CIE L*
Duroc	3.07	5.58	51.6
Berkshire	2.51	5.68	49.8
Chester White	2.39	5.70	51.3
Spotted	2.37	5.55	51.9
Poland China	2.18	5.61	50.9
Hampshire	2.09	5.58	49.0
Landrace	1.90	5.47	54.2
Yorkshire	1.70	5.47	53.4

[a]Adapted from Goodwin, 2004.

Table 3. Fatty Acid Profile of Loin Muscle by Breed.[a]

Breed	Total Saturated Fatty Acids, g/100g of lipid	Breed	Total Poly Unsaturated Fatty Acids, g/100g of lipid
Duroc	400.50	Hampshire	130.84
Berkshire	380.68	Landrace	130.16
Chester White	380.73	Yorkshire	130.10
Yorkshire	380.33	Spotted	110.55
Landrace	380.13	Chester White	100.79
Poland China	370.99	Poland China	100.41
Spotted	370.42	Berkshire	110.10
Hampshire	370.21	Duroc	90.61

[a]Adapted from Zhang et al, 2007.

acids in loin muscle. The Duroc breed had the highest estimate of total saturated fatty acids and the lowest estimate for polyunsaturated fatty acids. Conversely, the Hampshire breed had the lowest saturated fatty acid content in loin muscle and the highest loin muscle polyunsaturated fatty acid content. The Poland China breed had low estimates of both saturated fatty acid and polyunsaturated fatty acid content in loin muscle.

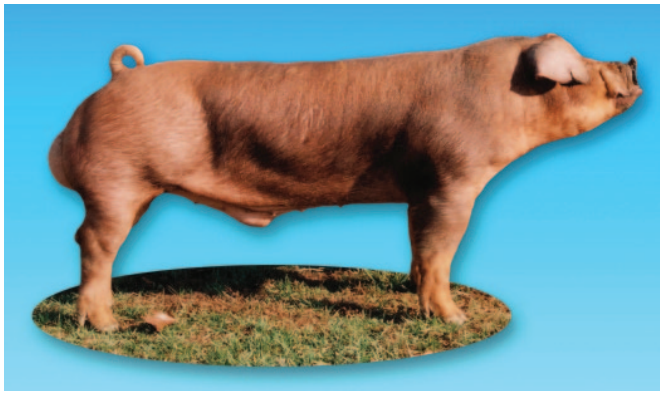
Taste panel evaluation. To better understand how the various attributes of pork may affect consumer experience, taste panels evaluate various criteria of cooked pork. These typically include tenderness, juiciness and pork flavor. Persons who serve on such panels are trained to distinguish a range of differences in these attributes. Panelists are given small samples to evaluate and then score each sample for these characteristics. Higher value scores typically indicate a more desirable attribute. In Table 4 are results from a trained panel that evaluated tenderness and juiciness of pork chops from traditional breeds. Higher values indicate more desir-

Table 4. Taste Panel Characteristics of Traditional Breeds.[a]

Breed	Tenderness	Juiciness
Berkshire	7.3	6.1
Hampshire	6.8	5.8
Chester White	6.6	5.8
Landrace	6.6	5.0
Duroc	6.3	5.4
Poland China	6.3	5.4
Yorkshire	6.3	4.9
Spotted	5.9	5.3

[a]Adapted from Goodwin, 2004.

Duroc boar



Graciously provided by the National Swine Registry.

Hampshire boar

Graciously provided by the National Swine Registry.

able tenderness or juiciness. The Berkshire, Hampshire, Chester White and Landrace breeds produced the more tender pork chops among the eight breeds. The Landrace breed produced loin chops that were not juicy, even though they were above average for tenderness. The Duroc breed was intermediate for both tenderness and juiciness.

Major Genes

Over the past several years, blood tests have become available within the pig industry to determine the genotypes of several major genes. Two of these major genes, HAL-1843 and Napole, have a detrimental impact on performance and meat quality. The status of these genes should be known within the breeding herd and certainly in purchased breeding stock, so that animals carrying the unfavorable copies of these genes can be excluded from the breeding herd.

HAL-1843. The HAL-1843 gene is commonly referred to as the "stress gene." Pigs that have one copy each of the normal and the mutant gene are considered to be heterozygous for this condition. Each copy of a gene within a gene pair is often called an allele. Pigs that are heterozygous for HAL-1843 typically have less backfat and higher percent lean than pigs that have two copies of the normal gene, but meat quality, as measured by color and pH, is typically poorer. Pigs that carry two copies, or alleles, of the HAL-1843 gene, are typically referred to as homozygous for HAL-1843, can be become easily overexcited when loaded and transported to market. This can lead to an increase in death loss before harvest. It is best to avoid having in the breeding herd any breeding stock carrying either one or two copies of this gene. Seedstock suppliers should be asked to provide assurance that all seedstock purchased are free of this gene.

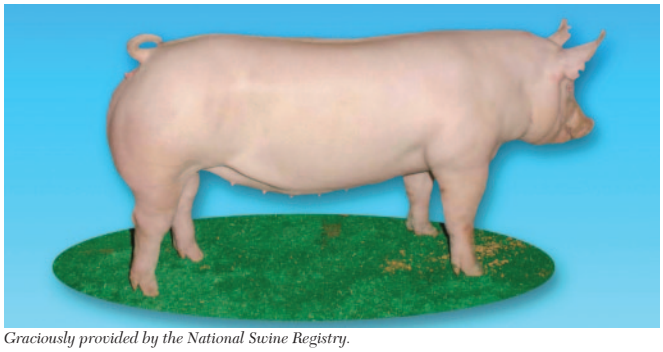
Napole gene. The Napole gene, often designated with the acronym RN, is typically found in the Hampshire breed. The gene has little or no impact on the growth and performance of live pigs, nor does it hinder their ability to be moved or transported to market. The effect of this gene is most notable after harvest. Fresh pork from pigs with one or two copies of this gene typically has lower pH, and the product is often pale and watery. Consequences are an undesirable retail display appearance and reduced consumer appeal, and poor processing characteristics. This gene should also be avoided in breeding stock. Seedstock suppliers should assure that purchased seedstock do not carry this gene.

Other Genes

There are other tests for major genes that can favorably influence pig performance and meat quality. Two of these genes may improve litter size. One of these genes is the estrogen receptor gene (ESR). The favorable allele can increase litter size by 0.4 pigs born. Females that carry two copies (homozygous) of the favorable allele may have an increase in litter size of 0.8, on average, compared with females that are homozygous for the undesirable allele. The second litter size gene is erythropoietin. Females that carry two copies of this gene may have increased litter size born compared with females that are homozygous for the undesirable allele.

Tests for genes that influence growth and meat quality traits are also available. One of these genes is called melanocortin-4 receptor (MC4R). One allele will cause pigs to grow faster; the other will cause pigs to be leaner and have better feed efficiency. Animals that have two copies of the growth allele should reach market weight sooner than pigs with two copies of the leanness and feed efficiency allele. Pigs that have two copies of the feed efficiency allele should have lower feed costs and have

Yorkshire gilt



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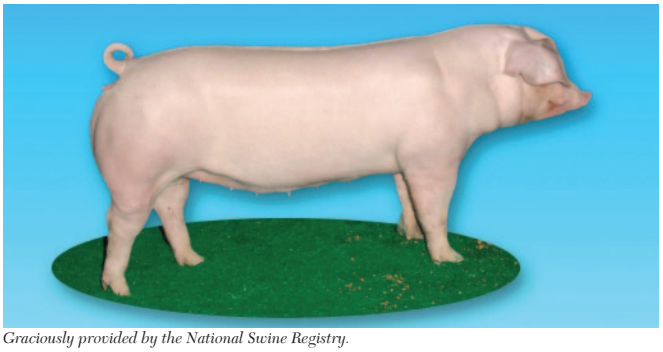
Landrace gilt



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better carcass merit. Another growth gene, cholecystokinin type A receptor (CCKAR), may cause animals to grow faster and reach market weight sooner if they carry one or both desirable alleles. A third gene, high mobility group AT-hook protein 1 (HMGA1), may cause pigs to be leaner and have higher lean percentage if they carry one or both copies of the desirable allele. These are not all of the genes that influence growth and carcass merit, but these genes have been shown to influence growth and carcass merit, and blood tests have been developed to detect them. Producers can request to have prospective purchased seedstock screened for these genes or test their internal parent candidates and use the results to select new parents that will produce offspring that better match the farm objectives for growth and carcass merit.

Two tests are available to check for genes that influence meat quality. One that can improve pH and color is protein kinase AMP activated gamma 3 subunit (PRKAG3). The favorable allele for PRKAG3 is actually in the same gene that is often referred to as the Napole gene but is in a different location than the unfavorable allele associated with the Napole gene. The other meat quality gene, calpastatin (CAST), controls tenderness and juiciness. Animals that have favorable alleles for PRKAG3 and CAST should produce fresh meat products that have desirable eye appeal and eating quality characteristics. Farms that market their pork directly to consumers or market into a pork chain whose specifications include favorable consumer attributes can screen prospective parents for these genes and choose animals that carry the desirable alleles. Parents that carry favorable alleles for these genes should produce progeny that yield pork with consumer appeal.

Producers should be aware that the effects of these genes can differ across different populations (breeds and breed crosses) and may be influenced by the environment in which pigs are reared. The experimental or industry conditions and breeds used in the estimation of the effects of these genes may differ from the environment or breeds used on individual farms. Farms that choose to select prospective parents that carry the desirable alleles for some or all of these genes should have some assurance that the estimated gene effects will be similar to what they will observe within their farm operations. Research to estimate the effect of these genes in various herds and breeds is ongoing. (For further information on tests for these genes, visit the Geneseek, Inc., Web site, **www.geneseek.com**.)

Housing

Animal housing plays an important role in determining what breeds and breed crosses should be used in a production system. Some breeds and breed crosses are better adapted than others to perform in group housing and extensive management. Specifically, sow breed crosses with a portion of their ancestry from breeds that are moderate in sow productivity may better withstand the environmental circumstances and the animal-to-animal interaction of group sow housing on extensively managed farms. Table 5 summarizes a study that evaluated three two-breed sow crosses. Sows either were housed in individual gestation stalls or were group housed in pasture lots during gestation throughout their productive lives. Yorkshire-Landrace crossbred sows, when housed individually over four parities, performed similarly to Duroc-Landrace and Hampshire-Landrace sows for pigs produced during their lifetimes. However, when group housed during gestation, the Duroc-Landrace and Hampshire-Landrace sows were similar in performance but superior to the Yorkshire-Landrace cross sows across

Berkshire

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Chester white

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Table 5. Number of pigs at 21 days of lactation through 4 parities.[a]

F_1 Sow-Cross	Stalls	Group Housing
Yorkshire-Landrace	28.4	24.7[b]
Duroc-Landrace	28.2	32.5[c]
Hampshire-Landrace	32.9	30.9[c]

[a] Adapted from Jungst et al., 1988.

[b,c] Means within a column with different superscripts differ ($P < 0.05$).

four parities. Producers housing sows in groups must take care to utilize breeds and breed crosses that can readily adapt to the conditions in which they will be raised.

Gilt Replacement Programs

Producers who wish to produce replacement gilts within the herd will need to use either a rotational, rota-terminal or grandparent terminal system. (These programs are discussed in the Michigan State University bulletin "Breeding Systems for Alternative Pork Chains: Breeding Programs.") The rotational and rota-terminal programs require that only boars or semen be purchased to maintain them. Grandparent programs do require routine purchase of gilts to maintain the system. Typically, rota-terminal and grandparent breeding systems are considered to be more profitable when operated correctly than rotational systems, but they do require more management input. Producers who produce their gilts internally must have a well thought through program to identify and track candidate replacement gilts from birth through selection and retention into the breeding herd. Specifically, producers must identify females to designate them as potential replacement gilts and also identify their breed of sire. That information must be retained throughout their lifetimes. Other useful information that should also be available from the identification system is the date or month and year of birth, and possibly the sow and litter from which the animal was born.

Purchasing all replacement gilts is an efficient and convenient way to manage a breeding system. Producers who choose this option do not have to identify gilts at birth and track them through the marketing phase and selection as replacement females. Producers who purchase all of their replacement females must work closely with their suppliers, however. To both maintain herd size and sustain a regular number of females farrowing, replacement females have to be entered into the herd on a routine basis, so producers will need to have regular deliveries of gilts throughout the year. In addition, the isolation and acclimation program must be operable year round. This will require appropriate facilities in which incoming gilts can be humanely housed regardless of weather conditions.

Producing gilts on the farm typically has lower variable or out-of-pocket costs than purchasing outside replacement gilts. The replacement gilt program is a year-round effort. Care must be taken to develop a disciplined mating system to ensure that an appropriate number of replacement gilts will be available for selection and introduction into the herd. Prospective replacement gilts produced in a rotational or rota-terminal program must be identified at birth and throughout their development as prospective replacements. At the time of marketing, prospective replacement gilts should be evaluated for conformation, underline and external genitalia soundness. Gilts that meet farm criteria for these characteristics can be retained and begin the process for introduction into the herd.

Poland China

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Spotted

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Breeding System Development

Producers developing a farm crossbreeding system need to clearly define and understand the objectives of the farm business. The farm objectives should lead to a farm operations plan that accounts for those conditions that are unique to the farm and encompasses the specifications of a particular marketing arrangement. Once these items are in place, a well-designed breeding program can be implemented to achieve the farm's objectives. To illustrate this, two scenarios will be outlined and discussed. For each scenario, one possible solution will be discussed, though multiple solutions could fit each scenario.

Scenario 1

Situation. A traditional farrow-to-finish farm with no more than 300 sows wants to fully employ two family members and produce market pigs that are not to be treated with any antibiotics after they reach 50 pounds. Pigs treated with antibiotics after 50 pounds will not be marketed through the target market. Sows are housed in individual stalls in both gestation and lactation. Market pigs are to meet specified meat quality specifications and be 50 percent of a designated terminal breed noted for meat quality.

Suggested solution. Keeping females in this scenario in individual stalls during gestation and lactation will allow for individual management of each sow. The sow cross choice should be one that will maximize sow productivity. The traditional choice would be a Yorkshire-Landrace cross, but a Yorkshire-Chester White cross could also be an option. Choosing a Yorkshire-Chester White cross could improve the potential for meeting the meat quality specification because the Chester White breed typically has better meat quality than the Landrace breed. These females could be purchased F_1 females or F_1 females produced from an internal grandparent production scheme. Another viable option would be to produce these females as backcross females in a rota-terminal scheme. Purchased or farm-produced gilts could be screened for the gene markers described earlier in this bulletin if those traits are relevant to the target market, and the information can then used in the selection process.

If the farm utilizes a rota-terminal program to produce replacement gilts from an internal maternal breed rotation, barrows and non-selected gilts produced from the maternal rotation would not qualify for the marketing program because their breed make-up would not be 50 percent of the designated terminal sire. Barrows and non-selected gilts would have to be marketed outside of the target market channel. It is not unusual for barrows and non-selected gilts from maternal matings to grade lower for lean percentage than pigs sired by a terminal boar. These market pigs from the maternal matings may be penalized in a grading program that rewards high lean percentage. Farms within this scenario that choose to use a rota-terminal system should investigate the marketability of the market pigs from the maternal matings to better understand the profitability of the entire system.

The terminal sire used in this scenario would be designated in the marketing specifications. Typically, it would be a Berkshire or Duroc sire. Marketing programs also exist that specifiy Hampshire-sired pigs that are negative for the Napole gene.

For this scenario, if the sow cross contains Chester White and the terminal sire is not above average for lean merit, the resulting market pigs may not do well in a carcass grading program based on lean percentage because Chester Whites are typically fatter than the other maternal breeds. This could reduce market income and farm profitability if pigs produced within this scenario are graded in a program that pays premiums and imposes penalties for differences in lean percentage. Care would need to be taken to choose family lines within the Chester White breed and the designated terminal breed that are better than the breed average for carcass merit so the pigs produced are not priced lower because of substandard carcass merit. Depending on the meat quality standards within the marketing specifications, the terminal breed could be one that has been selected for improved lean merit and still maintains acceptable meat quality. Terminal boars used in this scenario could also be screened for the growth, carcass merit and meat quality gene markers if the farm determines that screening could improve profitability and gain further advantage within the market chain.

Scenario 2

Situation. A farm wants to produce market pigs following a scripted management protocol. Pigs, regardless of age, are to be group housed. Sows are to be housed on pasture or dirt lots with access to shelter. Sows can farrow inside designated buildings but must raise their litters in pens. To meet the marketing objective, growing pigs are not to be treated with antibiotics. Pigs treated with antibiotics are to be marketed conventionally.

Suggested solution. Females in this scenario are to be kept in group housing and fed in groups as well. The sow cross choice for this scenario should be one that can withstand the social interaction of group housing and feeding. Several options should be compatible with this scenario. One of the breeds in the sow cross could be either Duroc or Hampshire; the other could be Yorkshire, Chester White or possibly Landrace. These females could be purchased F_1 females or F_1 females produced from an internal grandparent production scheme. Another possible option would be to produce these females as backcross females in a rota-terminal scheme. The challenge in producing females that are part Duroc or Hampshire in a backcross scheme is that some females will be two-thirds Duroc or Hampshire, and that potentially will reduce sow productivity. Another option could be to use Chester White and Yorkshire in a backcross within a rota-terminal program. Field reports suggest that this cross is more durable than a Yorkshire-Landrace backcross, but no comparative reports are available to confirm this.

The terminal sire would be a breed not used in the composition of the sow cross. For instance, if the Duroc breed were a part of the sow cross, then the breed of sire used to produce market pigs would not be Duroc. Care should be taken to choose a terminal sire that will optimize pig performance and improve profitability potential. Boars could also be screened for the growth, carcass merit and meat quality gene markers if the farm determines that screening could improve profitability and gain further advantage within the market chain.

In this scenario, there was no specification related to the carcass merit or meat quality of the market pigs produced. Whenever specifications on carcass merit or meat quality are present, the producer must consider the genetic merit of the sow cross as well as the terminal sire choice. If sows are to be housed in groups outside, it has long been thought that sows with average or above average fatness may better adapt to cold winter climates. Therefore, sires used to produce replacement females should be near or above breed average for fatness if the farm is located in U.S. regions with cold winters. It would also be critical to choose a terminal sire breed and boars within the breed that excel for carcass merit to produce market pigs. If carcass merit is not a concern within the market pigs, other characteristics that relate to the profitability of the farm or better fit the market specifications can be emphasized.

Conclusion

The breeding system and the breeds and animals chosen for its operation set the potential for performance and profitability. Proper development and operation of a crossbreeding system can optimize pig performance within farm operations and produce pigs to meet specific market scenarios. Understanding pig breed characteristics and how they can be systematically used in a crossbreeding system allows pork producers the opportunity to develop breeding systems that best fit their farm operations and the pork chain in which they market.

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