National Swine Genetic Improvement: An overview of essential program components and organizational structure needed for success

John MABRY
(Iowa Pork Industry Center, Iowa State University, Ames, IA 50014 USA)

Abstract: The swine industry in China is a thriving and evolving industry that has shown phenomenal growth over the past 10 years. To insure long term success and viability in a worldwide competitive industry such as pork, there is need for a National Swine Genetic Improvement Program. This program needs to draw on expertise and technology from across the world for its development, but it should be based on the structure of the pig industry in China and be led by Chinese scientists, administrators and producers. National Genetic Improvement requires more than just technology. A successful program of national genetic improvement will require cooperation from the industry and the government. The support for the university system is essential for the success of the pig industry. The university system has a vital role on education (of students, faculty, producers and consumers) as well as research and technology transfer. The government could also have a role in supporting the central test stations and AI stations across the country. An accurate and comprehensive pedigree maintenance system is essential to genetic improvement. And it will be vitally important to be active in the importation of new genetics to sample other populations.

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The swine industry in China is a thriving and evolving industry that has shown phenomenal growth over the past 10 years. New and modern swine farms have been started in locations across the country. Genetics has been imported from many different countries in an effort to upgrade the quality and efficiency of the traditional breeds of swine. But to insure long term success and viability in a worldwide competitive industry such as pork, there is need for a National Swine Genetic Improvement Program. This program needs to draw on expertise and technology from across the world for its development, but it should be based on the structure of the pig industry in China and be led by Chinese scientists, administrators and producers.

Our starting point is clear for all involved; 'National Genetic Improvement' requires more than just technology. For scientists working in the pig industry genetic technologies are fun to learn and exciting to use. Running a BLUP genetic analysis and examining the national sire rankings are an enjoyable part of our job. Testing new QTL's to locate a gene marker for an important trait, and seeing it succeed are very rewarding. However, to be successful in impro-

Biography: John MABRY, Dr., Professor, Iowa State University, IA Pork Industry Center, USA, E-mail: jmabry@iastate.edu

ving the genetic merit of a national population of pigs requires a programmatic approach that includes many technologies (genetic as well as others). And it requires a working relationship between the production sector, the scientific community, the government and the food industries for long term success.

Naturally, as a scientist involved in genetic improvement programs, we do start with traditional genetic considerations. We must design a program that will make genetic improvement through selection. This improvement is permanent and the most powerful tool we have for long term success. So we will focus on technologies that will maximize the accuracy of our selection, maximize the intensity of selection (while managing inbreeding), and try to maintain as much genetic variability as possible. Another powerful tool for permanent genetic progress is migration. Many Chinese have recognized that there are sources of superior genetics in several countries across the world, and have imported many pigs to China in an effort to improve on the traditional pigs breeds. To be successful in this endeavor, we must be sure that the pigs sampled to have a true genetic advantage, that we are accurately selecting the best pigs for importation, and the logistics (transportation, health screening, and red tape) are daunting. But this has been done quite successfully for the past few years. Another area of temporary genetic improvement that can be exploited is the use of mating systems to take advantage of heterosis and breed complimentarity. The proper design of the genetic system will insure performance advantages from this source.

As mentioned earlier, there are many program components that go beyond genetics that are needed to insure long term genetic improvement. Some to these program components that are essential to program success and that we will discuss include: (1) Animal ID (to include pedigree maintenance); (2) Farm data management systems; (3) Performance data collection systems; (4) Meat quality data collection systems; (5) Role of phenotypic selection; (6) Molecular genetics program; (7) Data processing and editing system; (8) Breeding value estimation; (9) Selection index formulation using BLUP Breeding Values; (10) Combining Quantitative Breeding Values with molecular genetic information; (11) Breeding Value reports for use in selection and mating decisions; (12) Quality control systems; (13) Central test station role; (14) Artificial insemination station role; (15) Genetic sampling (Migration); (16) Within farm genetic improvement program implementation; (17) Across herd genetic evaluation.

However, there are other factors that must be considered as this program of National Genetic Improvement for Swine is developed. The unique structure of the pig industry in China needs to be considered. Just how do you get the participation of the pig farms in different parts of China to be active and utilize the program? And what are the roles that are proper for the government to play in development and implementation of this program? First, I will briefly discuss each of the above program components as they can contribute to a successful program of National Genetic Improvement for Swine.

1 Animal ID system

A unique animal ID is required to accurately estimate breeding value, including correct parentage. The components of a unique animal ID include the breed of pig, birth date, farm of origin, litter number at the farm and the pig id within its litter. It would be best to have a common system across farms, but reality will force us to accept an animal ID system that is compat ible with and can be extracted from different farm data systems. Since this will be used nationally, it should be developed with national input.

2 Farm data management system (S)

Most data will be collected at the farm by farm personnel and will be used back at the farm by the same personnel. As farm size has grown, it is essential that these farms have available computerized data management systems for their usage to improve their productivity, preferably written in Chinese. However, not all farms will use the same data system. A compromise is for each system to have the capability to extract data easily for genetic program usage.

3 Performance data collection system

As we strive to make genetic improvement in traits of economic importance, the first step is to correctly measure the traits of interest. These measurement systems must give accurate measures of performance, be consistent in their expression of the traits, be flexible as factors of economic return change, must relate in some way to the profitability to the pig producer, and must be comprehensive. Genetic improvement targets reproductive traits, growth traits, composition traits and meat quality traits.

The most variable of the traits we select on with the lowest heritability, greatest response to heterosis and large economic importance are the reproductive traits. We need to improve fertility of the sow, perhaps through selection for litter size born alive. We need to improve the milking ability of the sow (for greater piglet survival and future growth rate), perhaps by measuring litter weaning weight, or through a correlated response approach. Non-productive sow days need to be minimized, genetically through selection for a shorter wean to first service interval (easily measurable, adequate heritability). And difficult to measure traits such as age at puberty, appetite and sow longevity need to be addressed also. Luckily, age at puberty and sow appetite are improved as a correlated response to selection for faster growth rate. And sow longevity can be improved via phenotypic selection.

The postweaning traits include growth, composition, feed conversion and meat eating quality. Selection for faster growth will lower cost of production, improve feed conversion, improve sow appetite and lower age at puberty in replacement females. A standardized measure of growth, such as days to market weight (such as 114 kg) needs to be utilized across herds. It is essential that we maintain a product with a desirable composition (adequately high lean percentage but with no meat quality problems). To accurately measure composition, it is best to use ‘Real Time Ultrasound’ measures of backfat and loin muscle area. Feed conversion will always be very economically important, but equally hard to measure on the individual animal. Luckily, this can be improved from indirect selection for fast growth and high lean composition.

4 Meat quality data collection system

The meat quality traits are not in the pricing structure of many countries at the present time, however, these are economically important in every country. Meat that is too lean, without adequate intramuscular fat, or with too low a pH creates economic loss through excess purge and a lowering of repeat pork purchases. To make improvements here, the meat quality traits to be selected on must be identified, preferably measurable on the live animal with an accurate estimate of economic importance. This may be difficult to measure at the farm, and might take a more centralized program approach for long term improvement. Luckily, advances in molecular genetics offer great promise in making meat quality improvements.

5 Role of phenotypic selection

While not as 'flashy' or technologically exciting as BLUP and QTL's, there is a real need to include phenotypic selection in our genetic improvement programs. As we have made success in selecting for extremes in leanness, high growth rate and large litter size, we have seen corresponding declines in fitness in those genetic programs that did not include phenotypic selection for structural soundness. Sow longevity is reduced, sow mortality has risen and post-weaning death losses have multiplied. A successful genetic improvement program needs to include selection for structural soundness (feet and legs, hip structure, overall conformation), as well as selection for reproductive soundness (teat number and quality, vulva structure, testicular development). In addition, selection against abnormalities such as ruptures and hernias is essential. New research in molecular genetics also offers promise in reducing costly genetic abnormalities.

6 Molecular genetics program

The trendiest and flashiest area of genetic improvement over the past few years, and the area of tremendous financial investment are in the area of molecular genetics. This approach has been successful in improving meat quality (Halothane gene and Napole gene markers) across different populations of pigs, and in improving growth rate, feed conversion and litter size in targeted populations of pigs. Very importantly, this technology offers our best chance for future improvements in traits such as genetic abnormalities. However, challenges still persist with these technologies (expense, repeatability across populations, access to successful markers, etc). Advances in molecular genetics cannot be done at the farm level and will need to be approached at the university, government and breeding company levels.

7 Data processing and editing system

After the traits to select have been identified and correctly measured, a system is needed to edit the data, check for accuracy, make corrections where needed, and transfer the data to the program staff where breeding values will be estimated. Common mistakes made in data measurement include simple typographical errors, reading the numbers incorrectly, outlier records, etc. These errors can occur at all input points, and a system to find and fix these errors is essential. This system will need to include both computerization as well as human input.

8 Breeding value estimation

After the performance data is collected on the economically important traits, animal breeding values (BV) need to be estimated for usage in selection, culling and mating decisions. One question that needs addressing is where are these BV estimates to be made? The technology for BLUP estimates of BV have been simplified so they can be estimated and used directly on the farm by farm personnel, if the system is properly set up by a trained animal geneticist. But any BV estimates done at the farm will include only the data from that farm, and there is a need to examine the genetic merit of animals across herds. So BV's must also be estimated (perhaps on an across herd basis) at a central location. And several areas must be considered in setting up the BV estimation program. Will the data be adjusted for known non-genetic sources of variation, or will these be accounted for in the analysis through the use of fixed effects, random effects or covariates? What models of genetic analysis will be utilized (fixed effects, random effects, covariates, interactions)? Most BV estimation programs require prior information on the variance component structure of the traits in the population, where will these be estimated? At one time there were challenges in getting access to accurate BLUP programs to estimate BV's; luckily that is no longer a problem. And how often will these BV's be estimated. The simple rule is that they must be estimated at a location and a time that does not delay their usage in on-farm selection and mating decisions.

9 Selection index formulation using BLUP breeding values

In order to make concurrent improvement in multiple traits of economic importance, selection indexes must be used as a tool for combining traits for multiple trait selection. These indexes must relate to profitability of farms using terminal crossbreeding systems in China. A maternal index for use in maternal breeds, such as Landrace and Large White (or Yorkshire) pigs needs to be formulated. These should include reproductive traits (primary role of maternal breeds in terminal crossbreeding systems), growth and composition traits (since maternal lines still provide half the genes to the market animals) and meat quality traits if available. Generally these indexes are expressed on a litter basis since a maternal female influences profit based on the litters she produces (or a maternal sire on the litters of their daughters). A separate terminal index needs to be developed for use in terminal breeds, such as Duroc. The terminal index should include the traits that the terminal sire influences in the market animal. This includes growth traits, composition traits, and meat quality traits if available. The weightings used in these indexes should be based accurate economic information as it applies to the Chinese marketing and production systems. In addition, profitability is not always a linear function. Extremes in leanness for instance, may result in correlated decreases in meat quality that preclude the use of a strictly linear index. The inclusion of threshold adjustments to the BV indexes should be considered for program usage.

10 Combining quantitative breeding values with molecular genetic information

As we develop more accurate estimates of molecular genetic merit, we must develop a system to include this new information into our system of index calculation for selection decisions. While this may be done as an independent culling level, there are other approaches that also need to be examined.

11 Breeding value reports

After estimation of breeding values and selection indexes, this information needs to be reported to the producer for their usage in selection and mating decisions. This information must be available for use at points in the production cycle that offer the opportunity for decisions to be made. One opportunity is at the weaning of sows. At this time there is a need to identify superior sows for purebred mating decisions and to identify the worst performing sows for potential culling. Since the sows weaning data needs to be included in this decision, there is a time interval of no more than three days from when sows are weaned until the time the selection decision will be made. Therefore a timely system of BV estimation and report formulation is essential. Another point of selection opportunity is when replacement gilts are chosen and boars for use in AI (artificial insemination) are selected. These BV based reports are essential for usage, along with phenotypic selection at these times.

12 Quality control program

As with any process, an accurate and adequate program to insure quality control is essential. As breeding values are estimated for animals with pedigree information, mistakes are often made in parentage. Mistakes such as inconsistent parentage or inconsistent sex do happen and need to be found and corrected. Luckily, these checks can be computerized for programmatic ease. While this program will provide accurate estimates of breeding value and selection indexes for farm usage, the actual selection decisions that are made need to be monitored over time. Programming to evaluate the realized selection differentials can be developed that will assist in this area. The estimation of farm genetic trends need to be done on a regular basis and discussed with each genetic farm. Percentage breakdowns done on a periodic basis can be used for benchmarking to see the quality of animals being selected from a numbers standpoint. Who will conduct these programs is an area of concern where decisions need to be made and where assistance will most likely be needed.

13 Central test station role

Central test stations have long been used in the swine improvement industry as a method of measuring performance of diverse genetics when raised in the same environment. Removal of these environmental effects has resulted in more accurate estimates of breeding value. However, with the advent of AI, more genetic ties have been created between farms using common animals, and most growth testing is now done using on-farm data and BLUP breeding value estimation procedures. However, there are some traits that are not easily measured at the farm level that could be measured at central test stations. Traits such as meat quality and feed conversion are possibilities. These central test stations can also offer the opportunity to demonstrate new technologies such as Real Time Ultrasound estimation of composition. The challenges with the operation of these central test stations are who owns them, who pays for them and who manages them. However, they do offer promise for usage in a national genetic improvement program for swine.

14 Role of artificial insemination stations (AI studs)

Artificial insemination is an essential technology for rapid and lasting genetic improvement. It is essential for dissemination of superior genetics to different farms. When animals are used to sire offspring in different farms, genetic tie and connectedness are created which are essential for accurate across herd genetic comparisons. And AI studs provide a high health procedure for genetic transfer. However, significant questions arise as these AI studs are considered: who owns the AI studs, who do they sell semen to, and where do they get the boars for the stud? This is perhaps an area for both private and governmental participation.

15 Genetic sampling (migration)

Swine production and swine genetics are

worldwide industries. As you try to upgrade native breeds of swine with international genetics, other countries offer promising lines and animals to sample and to see how much they improve the genetic merit of pigs in China. An organized program of genetic sampling can add to the genetic improvement realized by all countries. However, it is essential to be efficient in your sampling. You must go to populations that have successful genetic improvement programs, and can accurately identify the genetically superior animals, such as the STAGES program in the USA. The importation process must be done in a manner that does not create health concerns. And after importation, it is essential that you accurately monitor the success of the offspring from the imported animals. This is for information pertaining to future sampling. Migration has shown itself to be essential in reacting to changing selection goals in speeding up the response to the new genetic needs.

16 Within farm genetic improvement program

National genetic improvement programs should include both within farm and across farm components. It is now easy to implement BLUP selection technology at commercial farms for use in reproductive traits. BLUP technology can be used at genetic farms for all traits in the selection program. And phenotypic selection can be used at all farms also. Genetic improvement at the national level will be greatly enhanced if within farm genetic improvement programs are included in the national program. Part of this is from additional selection intensity, and part is from greater support for the program at the farm level since they will feel more a part of the national program.

17 Across herd genetic evaluation

Since a genetic population involves many different farms, with different management and environments, accurately identifying genetically superior animals across farms can add to national genetic improvement. This has been essential to the national genetic improvement in the United States. However, you must have the different genetic farms participate in the program. There must be genetic ties between the farms for the connectedness needed for accurate across herd genetic comparisons. Then the proper technologies and methodologies must be implemented at the national level for accurate across herd genetic comparison to be made.

The development and implementation of a ‘National Genetic Improvement Program’ for the swine industry in China is an effort that can greatly add to the domestic population. The country is now evolving from local pig breeds to more efficient pig breeds and animals and genetic programs. New farms are larger, use more technology and are more business oriented. It takes capital to invest in these new and more expensive farms, so ownership is increasingly protective of its investment. These new farms may prefer to operate independently of other farms in terms of their genetic program. A question that will be faced is whether they will participate in a ‘National Genetic Improvement Program’? While they will probably be very open to assistance in implementing new technology on their farm, the concepts of sharing data with a national organization and being compared to other genetic farms will most probably meet with some resistance. These challenges must be considered as the ‘National Genetic Improvement Program’ is designed and implemented.

A successful program of national genetic improvement will require cooperation from the industry and the government. There are several potential roles for the government in a 'National Genetic Improvement Program.' The support for the university system is essential for the success of the pig industry. The university system has a vital role on education (of students, faculty, producers and consumers) as well as research and technology transfer. The government could also have a role in supporting the central test stations and AI stations across the country. An accurate and comprehensive pedigree maintenance system is essential to genetic improvement, and the government could be an active participant in this area. And it will be vitally important for the government to be active in the importation of new genetics in the area of biosecurity.

This conference was designed to lay the groundwork for leaders in China to gain information that might assist them in making decisions about how to structure a 'National Genetic Improvement Program' for swine, and to discuss the components that are needed and could be utilized. Now it is up to leaders in China to make decisions and go about implementation. Decisions include what needs to be done next, what can be done successfully, what are the best approaches to implementation, what are the roles and responsibilities for the people that make a program successful, and what is the role of each of the industry participants? The people involved in this conference offer their support for you and others in accomplishing your goals and look forward to working with you in the future. We have tried to encapsulate the scope and depth that the challenges involved in development and implementation of a 'National Genetic Improvement Program' for swine in China. We have offered information, suggestions and advice based on our experiences in developing and implementing programs such as this. We offer assistance, technology that we have developed, and encouragement for your success in improving swine genetics in China.

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译文

国家猪遗传改良:成功所必需的计划要素和组织结构述评

John MABRY

(Iowa Pork Industry Center, Iowa State University, Ames, IA 50014 USA)

摘要: 中国的养猪业是一个繁荣发展的行业, 过去 10年呈现出显著的增长. 在像养猪业这样面临全球激烈竞争的行业, 要想长期保持成功和活力, "国家猪遗传改良计划"是必不可少的. 制定这一计划需要吸收世界范围内专家的成功经验和技术, 但必须以中国养猪业现有框架为基础, 由中国自己的专家、管理人员和生产者完成. "国家猪遗传改良计划"需要的远不仅是技术, 它的成功取决于养猪生产者与政府的密切合作, 而来自大学的技术支撑是其成功的关键. 在这一计划中, 大学在教育(学生、教师、生产者和消费者)、以及研究和技术传递中起了至关重要的作用. 政府可以在全国范围内的测定中心和人工授精中心方面扮演重要的角色. 一个全面和准确的种猪系谱记录系统是遗传改良的基础, 这对于从其他群体引进新遗传素材有着重要的作用.

关键词: 猪; 国家遗传改良计划; 组织结构

中国的养猪业是一个繁荣发展的行业, 过去 10年呈现出显著的增长, 全国各地都出现了新型现代化的养猪场. 为了努力提高猪传统品种的生产性能和生产效率, 从不同国家引入了大量的遗传资源. 在像养猪业这样面临全球激烈竞争的行业, 要想长期保持成功和活力, 就需要一个国家猪遗传改良计划